#43775607

ID; 88077406

QL
696
.G285
N45
1998

THE LONG-TERM EFFECT OF FIRE ON SAGE GROUSE NESTING AND BROOD-REARING HABITATS ON THE UPPER SNAKE RIVER PLAIN

A Thesis

Presented in Partial Fulfillment of the Requirements for the

Degree of Master of Science

with a

Major in Wildlife Resources

in the

College of Graduate Studies

UNIVERSITY OF IDAHO

BLM LIBRARY
BLDG. 50
DENVER FEDERAL CENTER
P. O. BOX 25047
VER, CO 80225-0047

By

PAMELA J. NELLE

December 1998

Major Professor: Kerry P. Reese, Ph.D.

QL
696
G285
N45
1998

AUTHORIZATION TO SUBMIT THESIS

This thesis of Pamela J. Nelle, submitted for the degree of Master of Science with a major in Wildlife Resources and titled "The long-term effects of fire on sage grouse nesting and brood-rearing habitats on the Upper Snake River Plain", has been reviewed in final form, as indicated by the signatures and dates given below. Permission is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor Kerry Paul Reese Date 12-9-98
Kerry P. Reese

Committee Members R Gerald Wright Date 12-9-98
R. Gerald Wright

Stephen C Bunting Date 12/9/98
Stephen C. Bunting

Department Administrator Date 12/10/98
George W. LaBar

College Dean Alton G. Campbell Date 12/14/98
Alton G. Campbell

College of Graduate Studies Final Approval and Acceptance:

Jean'ne M Shreeve Date 12/21/98
Jean'ne M. Shreeve

43775607

THE UNIVERSITY OF IDAHO LIBRARY

MANUSCRIPT THESIS

The literary rights in any unpublished thesis submitted for the Master's degree and deposited in the University of Idaho Library are vested in the Regents of the University. This thesis is open for inspection, but it is to be used only with due regard for the literary rights involved.

ABSTRACT

This study is the first to examine the long-term impact of wildfire and prescribed fire on sage grouse (*Centrocercus urophasianus*) nesting and brood-rearing habitat. The study took place on the Upper Snake River Plain in southeastern Idaho, in Clark and Fremont counties, from May to August in 1996 and 1997. The area is mostly sagebrush-grassland, with mountain big sagebrush (*Artemisia tridentata vaseyana*) being the most common subspecies of sagebrush. A total of 20 different-aged burns were sampled, ranging from wildfires which burned in the 1960's to prescribed fires set in 1996. Canopy coverage of burned and unburned vegetation was sampled using the line intercept method and 2 * 5 dm quadrats, pitfall traps were used to determine invertebrate abundance, and plots were searched for sign of use by sage grouse.

No long-term benefit was detected as a result of burning sage grouse nesting and brood-rearing habitat. Burning had long-term negative impacts on nesting habitat; 14 years after burning sagebrush had not returned to preburn conditions. Mean sagebrush cover was 8% in 6-14 year old burns, compared to 18% in unburned vegetation, and mean sagebrush shrub height was 49cm in 6-14 year old burns compared to 71cm tall in unburned vegetation. No difference was detected in forb abundance between different-aged burns. A short-lived response was found in invertebrate abundance. The abundance of ants and beetles was significantly greater in the 1-year old burn category, but had returned to unburned levels by 3-5 years postburn.

Burning has long-term negative impacts on sage grouse nesting habitat on the Upper Snake River Plain and burning to improve brood-rearing habitat results in short-term benefits, if any. With respect to sage grouse habitat requirements burns should be small and

UNIVERSITY OF IDAHO LIBRARY

their location determined in relation to the age and structure of the vegetation in the surrounding area and the quality of nesting and brood-rearing habitat already offered by the unburned vegetation.

BLM LIBRARY
BLDG. 50
DENVER FEDERAL CENTER
P. O. BOX 25047
DENVER, CO 80225-0047

ACKNOWLEDGMENTS

This project was funded by the Bureau of Land Management and received support from Idaho Department of Fish and Game, and the University of Idaho. My thanks go to all who sweated in the sagebrush with me, especially Anna Owsiak, Dennis Aslett, Bryan Vogt, Kara Leonard, Anne Hilborn, John Hershaw, Jeff Copeland, and Scott Gardener. Thanks to Dr. Ding Johnson for his advice and help with the invertebrate work and my sincere gratitude goes to Shane Devilia and Hollie Ferguson for their patience and care sorting the invertebrate samples in the lab. I thank my major professor Kerry Reese for his guidance, help and friendship, and my committee, Gerry Wright and Stephen P. Bunting, for their contributions. Thanks also to Jack Connelly for his involvement at every stage of this study. Finally, my thanks and love to my husband, R.D. Nelle, for rescuing me from the field when it was all over, and for his infinite patience and indefatigable sense of humor ever since.

TABLE OF CONTENTS

AUTHORIZATION TO SUBMIT THESIS ii

ABSTRACT iii

ACKNOWLEDGMENTS v

TABLE OF CONTENTS vi

LIST OF TABLES viii

LIST OF FIGURES x

LIST OF APPENDICES xii

INTRODUCTION 1

STUDY AREA 5

OBJECTIVES 8

METHODS 9

- General methods 9
- Sampling shrub and forb components 9
- Sampling invertebrate abundance 10
- Determining sage grouse use of different-aged burns 11
- Predicting ant abundance using the density of anthills 11

METHODS OF ANALYSIS 12

- Vegetation data 12
- Invertebrate data 13
- Predicting ant abundance 13
- Sage grouse use of different-aged burns 14

RESULTS 14

- Group composition 14
- Effect of time-since-burnt on vegetation 20
- Effect of time-since-burnt on invertebrate relative abundance 31
- Predicting ant abundance using the density of anthills 31
- Sage grouse use of different-aged burns 36

DISCUSSION 36

MANAGEMENT IMPLICATIONS 56

LITERATURE CITED 60

UNIVERSITY OF IDAHO LIBRARY

APPENDIX 1 67
APPENDIX 2 69
APPENDIX 3 75
APPENDIX 4 81
APPENDIX 5 84

LIST OF TABLES

Table 1. Identifying vegetation groups, produced by a cluster analysis, by the age of the vegetation in each group, calculated as the time-since-burnt by a prescribed fire or a wildfire, Upper Snake River Plain, SE Idaho, 1996-1997 16

Table 2. Standardized canonical coefficients of the first canonical variable for elevation and the 10 variables used in the canonical analysis on data from Upper Snake River Plain, SE Idaho, 1996-1997 23

Table 3. Results of univariate tests for differences in vegetation characteristics among vegetation groups differing in time-since-burnt, Upper Snake River Plain, SE Idaho, 1996-1997 26

Table 4. Characteristics of groups identified by cluster analysis of vegetation data from the Upper Snake River Plain, SE Idaho, 1996-1997 27

Table 5. Composition of major forbs in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 29

Table 6. Mean % shrub cover by species in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 30

Table 7. Univariate tests for differences in invertebrate abundance in different-aged burns, and the first standardized canonical coefficient from a canonical analysis of invertebrate abundance, Upper Snake River Plain, SE Idaho, 1996-1997 32

Table 8. Dry weight (grams) of invertebrates in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 33

Table 9. Number of anthills per 100m^2 in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 34

Table 10. Results of a linear regression modeling the density of anthills against the time-since-burnt, the number of ants and the dry weight of ants caught in pitfall traps, Upper Snake River Plain, SE Idaho, 1996-1997 35

Table 11. Sage grouse use of different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 37

LIST OF FIGURES

Figure 1. Location of the study area in Clark and Fremont counties, SE Idaho 6

Figure 2. The age range and frequency of occurrence of vegetation in the 1-year-old burn group 17

Figure 3. The age range and frequency of occurrence of vegetation in the 3-5 year old burns group 18

Figure 4. The age range and frequency of occurrence of vegetation in the 6-14 year old burns group 19

Figure 5. The age range and frequency of occurrence of vegetation in the unburned group.. 21

Figure 6. The age range and frequency of occurrence of vegetation in the low elevation group 22

Figure 7. Multivariate profile of the separation of vegetation groups using the coefficients of the first canonical variable from a canonical analysis of vegetation data from the Upper Snake River Plain, SE Idaho, 1996-1997 25

Figure 8. Mean sagebrush shrub height in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature as used by nesting sage grouse. 40

Figure 9. Mean sagebrush % cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the minimum reported in the literature as used by nesting sage grouse................................. 41

Figure 10. Mean total shrub cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature as used by nesting sage grouse 43

Figure 11. Mean grass height in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature as used by nesting sage grouse 44

Figure 12. Mean grass cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the minimum reported in the literature as used by nesting sage grouse 45

Figure 13. Mean sagebrush shrub height in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature used during sage grouse brood-rearing 47

Figure 14. Mean sagebrush cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the minimum reported in the literature used during sage grouse brood-rearing 48

Figure 15. Mean total shrub cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the maximum reported in the literature used during sage grouse brood-rearing 49

Figure 16. Mean total forb cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature used during sage grouse brood-rearing 51

LIST OF APPENDICES

Appendix 1. Vegetation characteristics and transect locations within different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 67

Appendix 2. Shrub composition (% canopy cover) and sagebrush shrub height in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 69

Appendix 3. % cover of major and miscellaneous forbs, grass, litter and bare ground and grass height in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 75

Appendix 4. Dry weight and numbers of invertebrates collected in pitfall traps in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 81

Appendix 5. Numbers of sign of sage grouse in use plots and density of anthills in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997 84

INTRODUCTION

Sage grouse (*Centrocercus urophasianus*) are heavily dependent upon sagebrush (*Artemisia* spp.) habitat at every stage of their life cycle (Patterson 1952) and were once abundant and widespread in 15 states across the western United States and in 3 Canadian provinces (Braun et al. 1977). The conversion of sagebrush rangeland to grassland for livestock grazing or crop production has led to widespread loss, degradation and fragmentation of sage grouse habitat and concern over declining population numbers was expressed as early as 1906 (Patterson 1952). Sage grouse have since been extirpated from Nebraska, Oklahoma, New Mexico and British Columbia. They now exist in 11 states and 2 provinces, and populations across the entire present-day range are much reduced in number and restricted to localized areas. Data from 9 states indicated that over the previous 10 years breeding populations declined from the long-term averages by 17 to 47%, with an average overall decline of 32%. Production data from 5 states also showed a decline from the long-term average over the previous 10 years by 10 to 51%, averaging an overall decline in production of 26% (Connelly and Braun 1997). These declines continue and are causing concern among the public, biologists and wildlife managers.

Patterson (1952) estimated that current land use practices had destroyed approximately 50% of the original sage grouse range. Since then vast areas have been impacted by mechanical (beating, disking, and chaining) and chemical (spraying with herbicides) control methods, and more recently by prescribed fire. Historically, fire was the primary disturbance influencing secondary succession in the Intermountain west (Blaisdell et al. 1982, Pyle and Crawford 1996). In comparison with other control methods, fire would appear to be an ideal tool for sagebrush control. It is a natural force to which many

organisms are adapted, it is relatively inexpensive, and the application of prescribed fire is flexible. Using fire to control sagebrush has become increasingly popular and has been endorsed as a tool for meeting the diverse management objectives inherent in sagebrush control (Klebenow 1972). Klebenow (1972) proposed that by creating a mosaic of cover and food production through the burning of small areas, managers could increase forage for cattle and sheep and improve sage grouse brood-rearing habitat.

Sage grouse exhibit preferences for certain vegetation characteristics during nesting and brood-rearing, and the physiography, type, and density of vegetation have an influence on nesting and brood-rearing location and success (Klebenow 1969). Sagebrush is crucial to nest site choice and successful brooding, with each taking place in selected sagebrush habitats. The majority of hens nest under sagebrush (Patterson 1952, Klebenow 1969, Wallestad and Pyrah 1974, Rothenmaier 1979, Wakkinen 1990, Connelly et al. 1991), and select tall sagebrush bushes (Patterson 1952, Wallestad and Pyrah 1974, Rothenmaier 1979, Wakkinen 1990), offering taller grass and greater horizontal cover than typically found under other shrubs (Klebenow 1969, Wallestad and Pyrah 1974, Connelly et al. 1991). Total shrub canopy cover also influences nest site choice, as hens avoid very dense stands of sagebrush (>40% canopy cover, Klebenow 1969, Wallestad and Pyrah 1974, Braun et al. 1977, Rothenmaier 1979).

The height and density of sagebrush is also an important factor in choice of brood habitat, and broods appear to select shorter shrub heights and less dense sagebrush than those selected for nesting (Martin 1970, Wallestad 1971). Broods select sparser cover for feeding during the day (Klebenow 1969, Martin 1970, Peterson 1970, Wallestad 1971, Klott and Lindzey 1990), and denser cover (Wallestad 1971), and taller bushes for roosting under at

night (Dunn and Braun 1986). The density of sagebrush used also varies over the year, with areas of sparse cover being used early in the summer, and denser cover receiving more use later in the summer and fall (Wallestad 1971). In winter, sage grouse forage and roost where sagebrush height and canopy coverage is greatest and where the sagebrush exposure above snow is maximized (Hupp and Braun 1989, Robertson 1991).

As well as providing adequate shelter from predators and adverse weather, nesting and brood-rearing habitat must provide adequate food for hens and chicks. Forbs and insects are essential summer habitat components during the first 12 weeks of the chicks' life (Patterson 1952, Klebenow and Gray 1968, Peterson 1970, Wallestad 1975). Forbs make up between 73-81% of the diet of juvenile sage grouse (Klebenow and Gray 1968, Peterson 1970), and sites used by broods typically have greater forb frequency compared to random sites (Wallestad 1971, Dunn and Braun 1986, Drut et al. 1994a). Sage grouse summer movements appear to follow a moisture gradient, where the birds are presumably following the availability of succulent, green forbs (Klebenow 1969, Wallestad 1971, Fischer et al. 1996). Invertebrates appear to be critical during the first 2 weeks of the chicks' life (Klebenow and Gray 1968), and the most important Orders are the Orthoptera (primarily grasshoppers), Coleoptera (beetles) and Hymenoptera (ants). Grasshoppers usually predominate in the diet in early summer, while beetles and ants are consumed throughout the summer (Patterson 1952, Klebenow and Gray 1968, Peterson 1970). To successfully raise sage grouse in captivity, chicks required insects in their diet until they were at least 3 weeks old, and increased quantities of insects increased the survival and growth rate (Johnson and Boyce 1990). Drut et al. (1994b) found a correlation between the amount of forbs and

insects in the diet of chicks and the long-term productivity estimates of sage grouse from 2 areas.

Nesting and brood-rearing are important stages in the life cycle of sage grouse, and when unsuccessful will result in a reduction in the productivity of, and recruitment to, a population (Edelmann et al. 1998). Several studies have examined the immediate effects of fire on sage grouse habitat (Connelly et al. 1981, Gates 1985, Martin 1990, Benson et al. 1991, Robertson 1991, Fischer 1994), but no research has addressed the long-term effects of fire (but see Simes 1991 for a study of sage grouse use of 2 old burns). Cover types and species diversity of vegetation in disturbed areas change over time and therefore prescribed burning may have different short-term and long-term effects within a wildlife species' habitat (Bendall 1974). Habitat characteristics resulting from a regular prescribed burning program over an extended time period may result in significant areas of suboptimal nesting and brood-rearing habitat. This could be reflected in a change in the extent to which sage grouse use burned habitat, or in limited availability of optimal nesting and brooding conditions, potentially reducing a population's productivity. Understanding the long-term effects of fire on vegetation and invertebrates would allow managers to plan prescribed burning programs with minimum long-term impacts upon sage grouse nesting and brood-rearing habitat. The objective of this study was to test the research hypothesis that fire has a long-term negative effect on sage grouse nesting and brood-rearing habitat in Clark and Fremont counties in southeastern Idaho.

THE STUDY AREA

The study area was situated in southeastern Idaho on the Upper Snake River Plain, in Clark and Fremont counties (Figure 1), and encompassed an area of about 40,000 ha. The area is intermingled state, Bureau of Land Management, and private land, and includes parts of the Sand Creek Wildlife Management Area (WMA). Approximately 20,000 head of sheep and 1,660 head of cattle (G. Dawson, BLM, pers. comm.) graze it each year from May/June to September/October.

Mean spring and summer precipitation ranges from 20 cm on the southern end of the WMA, to 46 cm along Big Bend Ridge in the north, and temperature ranges from 4°C to 38°C during the spring and summer (D. Aslett, IDFG, pers. comm.). Elevation ranges from approximately 1430 m to buttes of 2440 m (Crowley and Connelly 1996). The area is mostly sagebrush-grassland. Mountain big sagebrush (*Artemisia tridentata vaseyana*) is the most common sagebrush, but three-tipped sagebrush (*A.tripartita*) occurs as well. Other shrubs include bitterbrush (*Purshia tridentata*), rabbitbrush (*Chrysothamnus* spp.), and horsebrush (*Tetradymia canescens*). Sand dunes in the southern end of the study area support stands of chokecherry (*Prunus virginiana*). A variety of grasses and forbs are found, including arrowleaf balsamroot (*Balsamorhiza sagittata*), tailcup lupine (*Lupinus caudatus*), bluebunch wheatgrass (*Agropyron spicatum*), thick-spiked wheatgrass (*A. dasystachyum*) and Nevada bluegrass (*Poa nevadensis*) (Dalke et al. 1963).

The combination of fire and conversion to farmland in Clark and Fremont counties in southeastern Idaho has created concern about the status of sage grouse habitat in this area. Available data indicate that the sage grouse breeding population in the study area declined significantly from the 1950's to the 1990's (Crowley and Connelly 1996). Lek attendance,

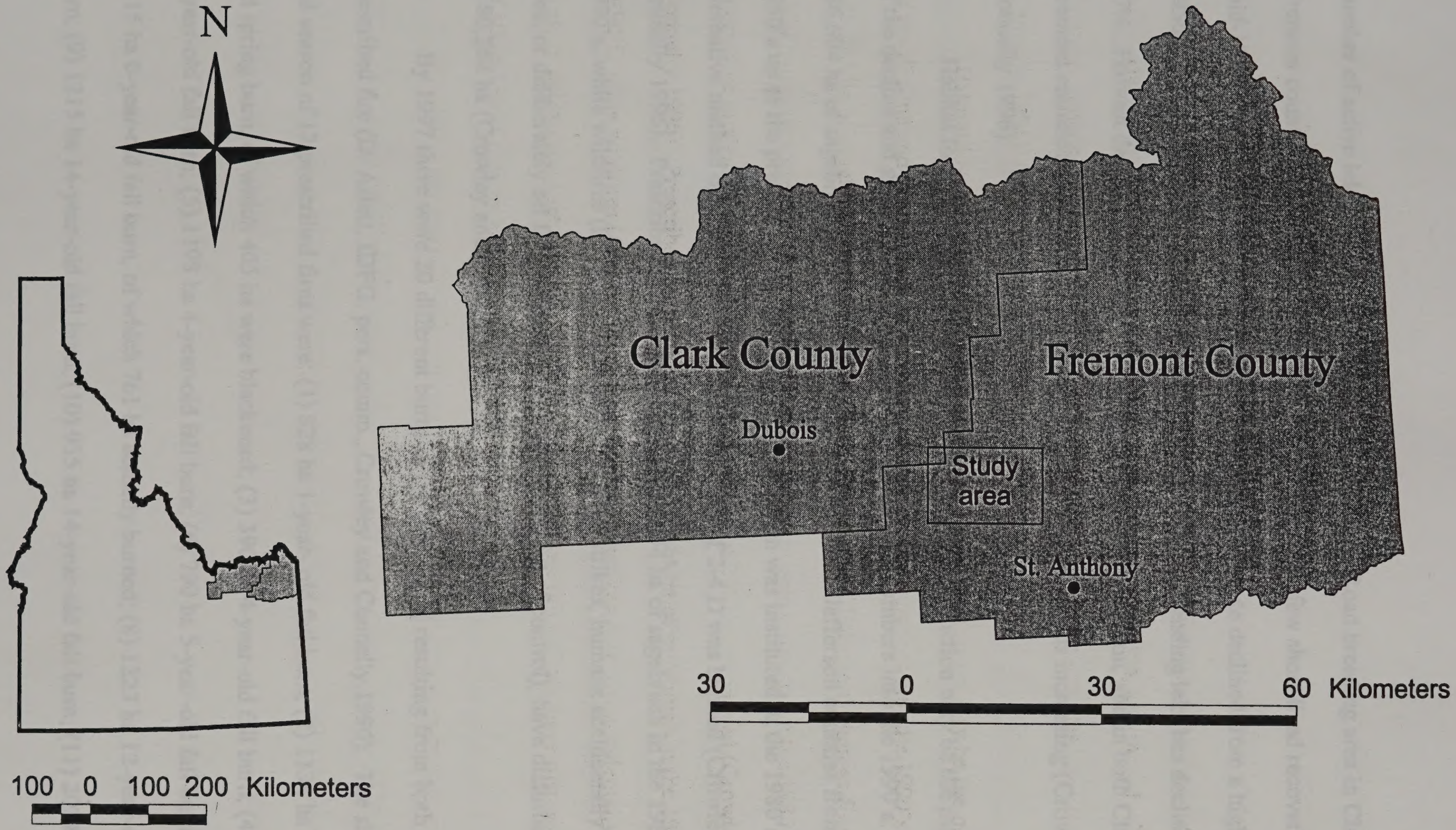

Figure 1. Location of the study area in Clark and Fremont counties in southeastern Idaho.

number of active leks, and production of birds in the Red Road breeding area in Clark and Fremont counties have all declined since the 1950's, with a few short-lived recoveries in the mid-1980's. The number of active leks on the Red Road route declined from a high of 18 in 1956, to 10 in 1970, to 4 in 1990 and the number of males attending leks has declined by 37%. Harvest data corroborates a declining sage grouse population, and in both Clark and Fremont counties the number of hours, or hunter effort, per bird is increasing (Crowley and Connelly 1996).

Habitat loss and degradation and consequent poor production may be the major cause of the decline and general lack of recovery of sage grouse numbers into the 1990's. At least 186,694 ha of sagebrush were treated in Clark, Fremont and Jefferson counties from the 1950's up to the present. A prescribed burning program was instituted in the 1980's as an alternative method of sagebrush control when the use of 2-4 D was banned (Crowley and Connelly 1996). Prescribed burning has removed 36,444 ha of sagebrush in the 1980's and 1990's, while wildfires (fires resulting from lightening strikes, humans accidentally starting fires, or deliberately set fires on private land that burnt out of control), have disturbed an area of 80,264 ha (Crowley and Connelly 1996).

By 1997 there were 20 different burns in the study area, resulting from both wild and prescribed fire (D. Aslett, IDFG, pers. comm., Crowley and Connelly 1996). The size, age and season of 12 prescribed fires were: (1) 828 ha 1-year- old fall burn; (2) 1134 ha 3-year-old spring burn, of which 405 ha were blackened; (3) 390 ha 4-year-old fall burn; (4) 672 ha 4-year-old fall burn; (5) 1198 ha 4-year-old fall burn; (6) 790 ha 5-year-old fall burn; (7) 1215 ha 6-year-old fall burn, of which 761 ha actually burned; (8) 1223 ha 12-year-old fall burn; (9) 1215 ha 14-year-old fall burn; (10) 955 ha 14-year-old fall burn; (11) 2024 ha 16-

year-old burn (no season reported); and (12) 3036 ha 16-year-old summer burn, of which 1215 ha actually burned (Crowley and Connelly 1996).

There were 8 wildfires in the study area. The size, age, season, and how each fire started were as follows: (1) 438 ha 8-year-old summer burn started by passing vehicle; (2) 336 ha 8-year-old summer burn started intentionally; (3) 227 ha 10-year-old spring burn started intentionally; (4) 559 ha 14-year-old fall burn started intentionally; (5) 22-year-old burn with no further information; (6) 27-year-old burn with no further information; (7) 36-year-old burn with no further information; and (8) a 36-year-old burn with no further information (Crowley and Connelly 1996).

OBJECTIVES

The objectives of this study were to: (1) describe changes in vegetation height and density in sage grouse nesting and brood-rearing habitat in different-aged burns as a result of prescribed burning and wildfire, (2) determine the changes in forb composition and abundance with time since burning as a result of prescribed fire and wildfire, (3) determine the insect populations during spring and early summer in different-aged prescribed fire and wildfire burns, (4) document the extent of use by sage grouse of different-aged burns on the Upper Snake River Plain, and (5) develop recommendations for fire management to help maintain the sage grouse population of the Upper Snake River Plain.

METHODS

General methods.

I carried out habitat sampling within the 20 burns (delineated by their burn perimeters) from May through August in 1996 and 1997. Burns were categorized as either a prescribed burn or a wildfire, and aged according to the time-since-burnt. Vegetation was considered unburned if there was no record of it having burnt in the past 37 years at the time of the study. I sampled 1-6 year old burns in both 1996 and 1997, and randomly assigned all other burns to either year. I randomly sampled 4 sites within each burn, twice in burned vegetation and twice in unburned vegetation due to the mosaic nature of burns in sagebrush. I sampled every site twice each field season. In 1996, I carried out vegetation sampling from the 3 - 23 June, and from the 20 July to 8 August. In 1997, I sampled vegetation from the 2 - - 16 June and from the 2 - 13 July. This resulted in 216 transects over 2 field seasons. At each random location I laid a 50-m tape measure, oriented north-south, to mark the transect, the ends of which were fixed using 0.75-m lengths of rebar and marked with flagging.

Sampling shrub and forb components.

I measured the percent shrub cover by species using the line intercept method (Canfield 1941), and at 5-m intervals along the transect I measured grass height (cm) at the tape and the tallest sagebrush plant (cm) within 1-m radius of the tape. Using the same 50-m transect used for the shrub and grass sampling, forb composition and abundance were measured using a 2x5 dm quadrat frame (Daubenmire 1959), placed at 1-m intervals along the transect. I recorded the percentage of grasses, litter and bare ground, as well as the percentage of the following forbs known to be important in the diet of sage grouse,

associated with good brood-rearing habitat, or indicators of disturbance: western yarrow (*Achillea millefolium*), buckwheat (*Eriogonum* spp.), *Phlox* spp., false dandelion (*Agoseris glauca*), wild onion (*Allium* spp.), dandelion (*Taraxacum officinale*), rosy pussytoes (*Antennaria rosea*), death camas (*Zygadenus venenosus*), prickly pear (*Opuntia polyacantha*), sego lily (*Calochortus* spp.), lupine (*Lupinus* spp.), prickly lettuce (*Lactuca serriola*), hawksbeard (*Crepis* spp.), common salsify (*Tragapogon* spp.), and prairie starflower (*Lithophragma* spp.) (Klebenow and Gray 1968, Peterson 1970, Wallestad 1975, Drut et al. 1994b, Pyle and Crawford 1996). I categorized these forbs as major forbs, and other forbs encountered as miscellaneous forbs.

Sampling invertebrate abundance.

I used pitfall traps (method modified from Fischer 1994) to sample the relative abundance of insects within burns. Sixteen test tubes were sunk flush with the ground in a 4x4 grid, 50 cm apart, within 20 paces of the southern end of each vegetation transect. The test tubes were filled with a 1:1 solution of water and ethylene glycol and were sealed with a cork until sampling began. I opened the pitfalls for a 24-hour period twice each field season. Invertebrate sampling began after each vegetation sampling period was finished, with approximately 1 month between the 2 invertebrate sampling periods. In 1996 invertebrate sampling was carried out from 25 June to 14 July, and from the 5 - 18 August. In 1997 invertebrate sampling was carried out from 18 - 27 June, and from 14 - 26 July. Insects caught were collected and stored in 70% alcohol. In the laboratory, invertebrates were separated into 3 Orders: Hymenoptera (ants), Coleoptera (beetles), and Orthoptera (grasshoppers). All other invertebrates were categorized as miscellaneous. Number of

individuals per sample of each Order and of the miscellaneous group was counted and the samples were oven dried for 24 hours at 100^0C, and weighed to 0.01g.

Determining sage grouse use of different-aged burns.

To determine the extent to which sage grouse used different-aged burns, I searched for signs of use by sage grouse in each burn. Using the vegetation transect as the southern boundary of the search area and extending the area to the western side, I delineated a 100x100m area by flagging every 20m and at each corner. I searched this area, hereafter referred to as a use plot, by walking back and forth in a grid pattern at approximately 10m intervals. I noted any sign of sage grouse use, such as droppings and feathers, and marked any feces found by spraying them with fluorescent paint. I also counted the number of birds flushed from each use plot. I surveyed the use transects twice in each field season, after completing the invertebrate sampling within each burn. Thus, in 1996 I searched use plots from 25 June to 14 July, and from 5 - 18 August, and in 1997 I searched use plots from 18 - 27 June, and from 14 - 26 July.

Predicting ant abundance using the density of anthills.

To test the hypothesis that the density of anthills in an area could provide an alternative method for estimating Hymenoptera abundance, I counted the number of anthills found within the use plots. This allowed me to compare density of anthills in different-aged burns to the biomass of Hymenoptera recorded in the same areas.

METHODS OF ANALYSIS

I used SAS (SAS Inst., Inc. 1988) and SPSS (SPSS Inc., 1992) to analyze the data, and considered differences significant if $P \leq 0.05$. I transformed proportional data using the arcsine of the square root (Zar 1984) and plotted histograms to determine whether data were normally distributed. For univariate tests I used the appropriate non-parametric test when data were non-normal. I was unable to determine whether or not vegetation had burned in areas categorized as burned by wildfire in the 1960's (numbers 7 and 8 on page 7) due to regrowth of vegetation. As a result I considered all vegetation from these sites as unburned. For the prescribed burn transects from the 1990's that were sampled twice in both years (numbers 2 to 7 on page 6) I averaged the 4 samples of each transect. I also pooled data between months for all other transects that were sampled in either year. This resulted in 84 observations from the 2 seasons of fieldwork.

Vegetation data.

I used an exploratory cluster analysis (Hair et al. 1995) to produce a natural structure of vegetation characteristics based on a multivariate profile. I used 10 variables known to be important in nesting and brood-rearing habitat and/or strongly affected by fire. These were: (1) % sagebrush cover (2) % bitterbrush cover (3) % cover of standing dead shrubs (4) % total live shrub cover (5) sagebrush height in cm (6) grass height in cm (7) % grass cover (8) % litter cover (9) % cover of major forbs, and (10) % cover of miscellaneous forbs. The number of groups chosen from the cluster analysis for use in subsequent analyses was based on the minimum number of clusters that were characterized by identifiable and useful (from a management standpoint) age categories.

I used a confirmatory MANOVA (Hair et al. 1995) to confirm that clusters were statistically distinct and have reported the P values purely as descriptive measures of how different clusters are. I used a Kruskal-Wallace one-way analysis of variance (Zar 1984) describe how the 6 forbs identified in the literature as the most important food items in sage grouse diet (common yarrow, lily, hawksbeard, prickly lettuce, dandelion and yellow salsify) differed in abundance among different-aged burns.

Invertebrate data.

I used a MANOVA (Hair et al. 1995) to describe relative invertebrate abundance in different-aged burns, using the same grouping of observations suggested by the vegetation cluster analysis to group the invertebrate data.

In both MANOVA's I used Pillai's trace statistic as the test statistic, Tukey's multiple comparison test (Zar 1984) for post-hoc comparisons, and a canonical analysis (Hair et al. 1995) to determine which variables were driving the differences between groups.

Predicting ant abundance.

I used linear regression (Zar 1984) to model the density of anthills against ant biomass (dry weight in grams) and numbers of ants to test the null hypothesis that the density of anthills in an area is not correlated with ant abundance. I also modeled the age of the vegetation with the density of anthills to test the null hypothesis that the density of anthills does not increase with increasing time-since-burnt.

Sage grouse use of different-aged burns.

I used a Kruskal-Wallace one-way analysis of variance (Zar 1984) to describe differences in the level to which sage grouse used different-aged burns. The amount of use was measured as the number of piles of sage grouse droppings seen, number of feathers, or number of birds flushed per $100m^2$ use plot. I also used multiple regression (Hair et al. 1995) to test for a relationship between the level of sage grouse use of different-aged burns and sagebrush height and density, the total abundance of major food forbs and the total abundance of invertebrates (ants, beetles, grasshoppers and miscellaneous invertebrates).

An unavoidable confounding variable was the effect from cattle and sheep, which graze on both private and public land within the study area. I assumed that grazing pressure was equal on all sites and between years, and therefore differences among burns could be attributed to the effects of fire.

RESULTS

Group composition.

I did not distinguish between the effects of prescribed fire and wildfire in the subsequent analysis and discussion as there were no wildfires younger than 8 years old and only 5 prescribed fires more than 7 years old at the time of sampling. I also assumed that there were no differences in prescribed fire and wildfire effects upon vegetation and invertebrates.

Based on identifiable and useful age groups I selected 5 clusters as the number of groups to be used in subsequent analyses. There was 1 transect that was not included in a cluster which I classified as an outlier and excluded from the subsequent analysis. I

described clusters according to the age class of the vegetation and the type of treatment (prescribed fire, wildfire or unburned, i.e. the controls) in each cluster. Although there was a range of different-aged burns and treatments within clusters, 4 relatively distinct age classes emerged. One cluster was difficult to describe with respect to vegetation age or treatment and other criteria had to be used to characterize it. Clusters included transects from burns older or younger than the age class subsequently used to identify the cluster. This could reflect variations in vegetation due to topography, grazing pressure, post-climatic conditions or fire intensity.

The first cluster (n = 5) contained all prescribed fire observations with a median vegetation age of 1year and was labeled the 1-year-old burn group (Table 1, Figure 2). One out of the 5 observations (20%) was from a 14 year old burn, which was noted at the time as receiving heavy grazing pressure from sheep which could explain why it was clustered with the remaining 4 transects, which were from the 1 year old burn. The 1-year-old burn group was typical of vegetation immediately after a disturbance. The second cluster (n = 9) had a median vegetation age of 4 years old and 89% of observations were of prescribed fire which ranged from 3-5 years old (Table 1, Figure 3). One out of 9 (11%) transects in this cluster was from a 26 year old burn, and was likely included in this cluster as a result of grazing by sheep, which was noted as appreciable at the time. This 3-5 year old burn group was representative of an early seral stage in succession. The third cluster (n = 16) was composed of the following transects: 44% prescribed fire, 37% wildfire and 19% unburned vegetation, with 69% of transects 6-14-years post-burn. It had a median age of 10-years-old (Table 1, Figure 4). Of the remaining transects, 3 were from unburned vegetation (36+ years old) and were noted at the time to apparently be heavily impacted by cattle grazing. The remaining

Table 1. Identifying vegetation groups, produced by a cluster analysis, by the age of the vegetation in each group, calculated as the time-since-burnt by a prescribed fire or a wildfire, Upper Snake River Plain, SE Idaho, 1996-1997.

Group	n	Minimum age (years)	Maximum age (years)
1-year-old burn	5	1	14
3-5-year-old burn	9	3	27
6-14-year-old burn	16	4	36
Unburned (36+ years old)	48	12	37
Low elevation	5	10	37

UNIVERSITY OF IDAHO LIBRARY

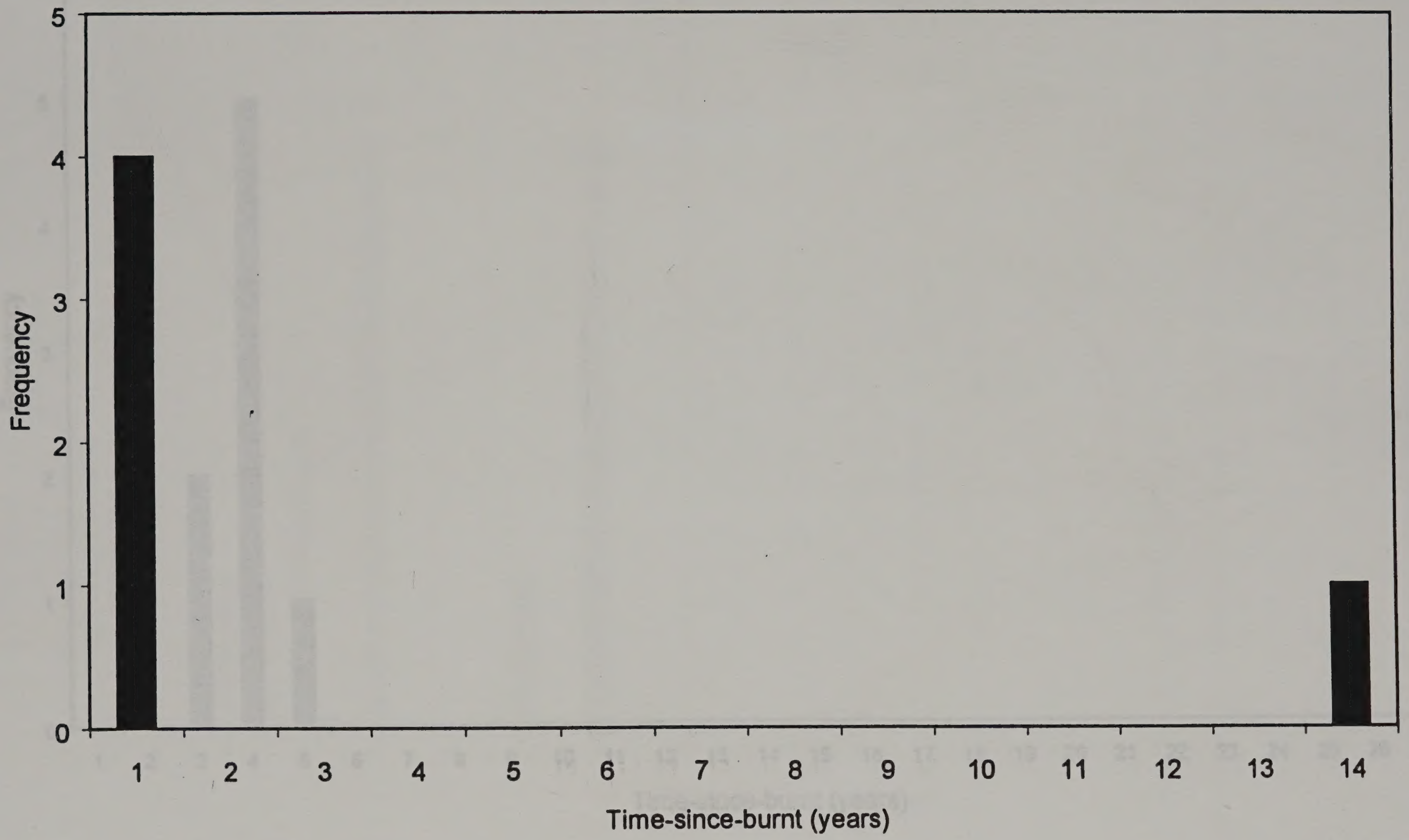

Figure 2. The age range and frequency of occurrence of vegetation in the 1-year-old burn group.

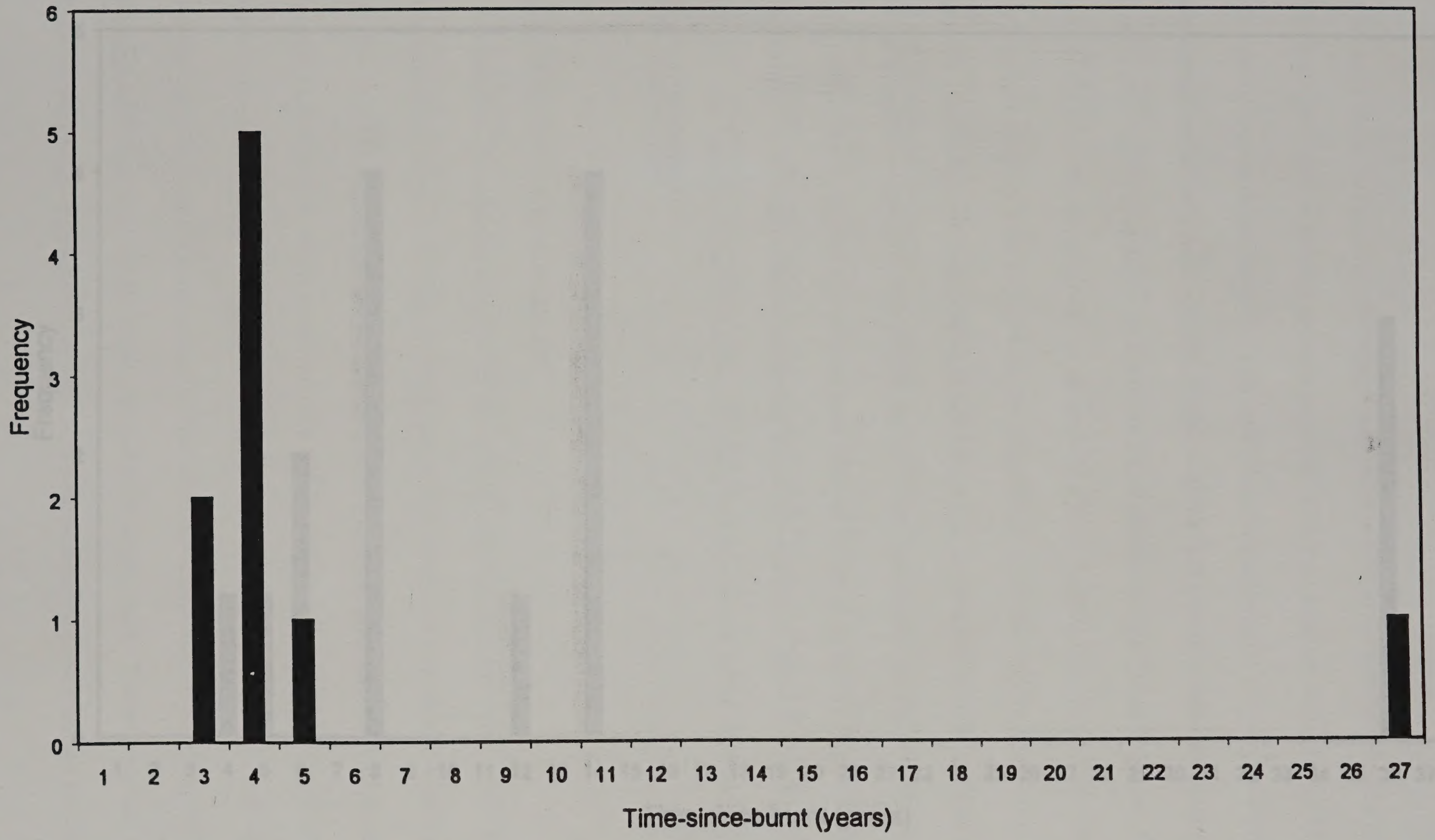

Figure 3. The age range and frequency of occurrence of vegetation in the 3-5 year old burns group.

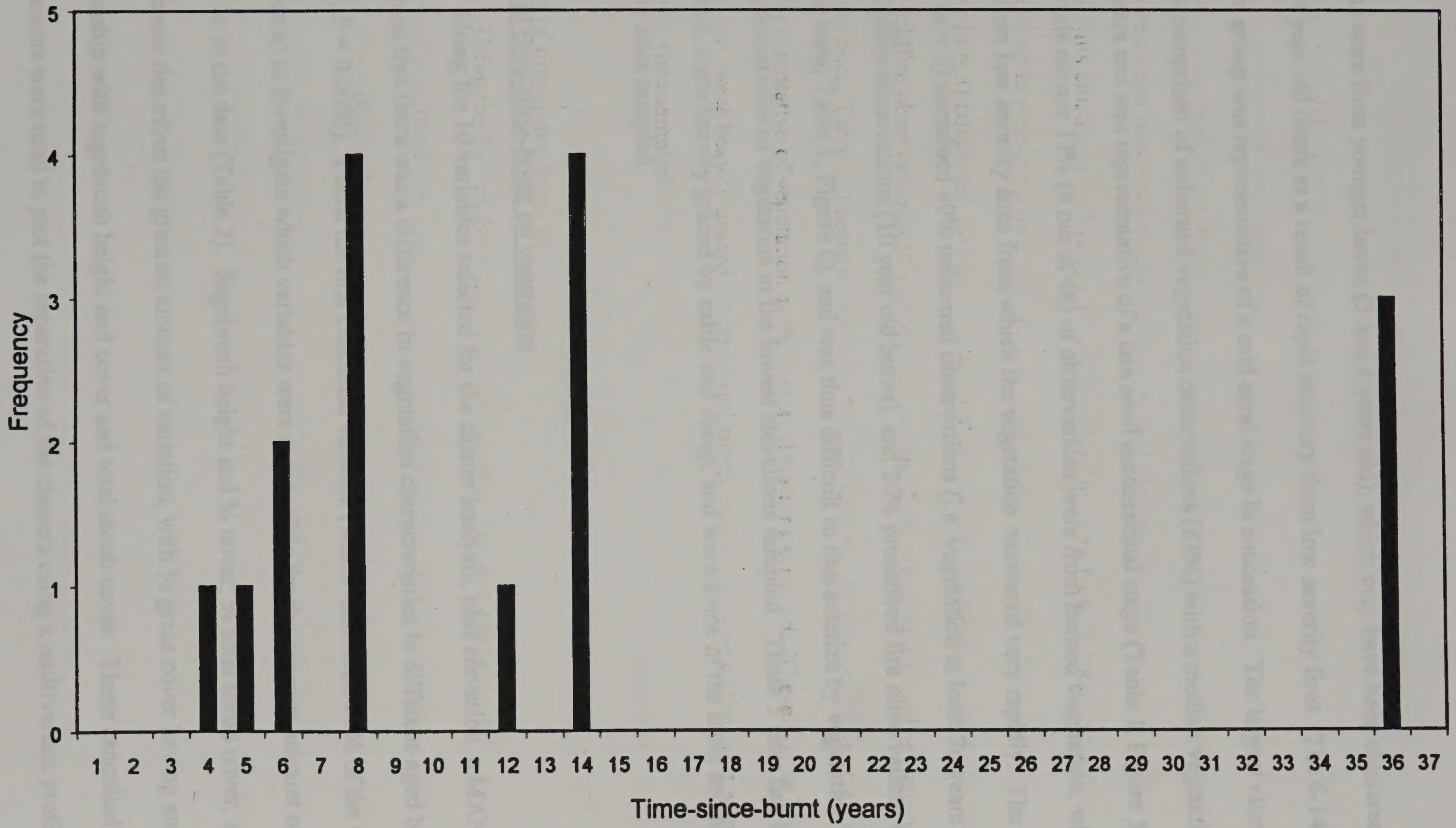

Figure 4. The age range and frequency of occurrence of vegetation in the 6-14 year old burns group.

transects were from younger burns (3 and 4 years old), which may have been clustered with the 6-14 year old burns as a result of rapid recovery from low severity fires. The 6-14 year old burn group was representative of a mid-seral stage in succession. The largest cluster (n = 48) was comprised of unburned vegetation observations (83%) with a median vegetation age of 36 years and was representative of a late seral successional stage (Table 1, Figure 5). Within this cluster 17% (8 out of 48) of observations were from burned vegetation, which may reflect low severity fires from which the vegetation recovered very rapidly. The last cluster (n = 5) contained 40% unburned observations (i.e. vegetation at least 36 years old), 40% wildfire observations (10 year old burns), and 20% prescribed fire observations (a 16-year old burn, Table 1, Figure 6), and was thus difficult to characterize by vegetation age, but was representative of vegetation at the lowest elevations sampled. These 5 sites had very sandy soil, were heavily grazed by cattle and sheep, and were some of the most southerly and westerly sites sampled.

Effect of time-since-burnt on vegetation.

Using the 10 variables selected for the cluster analysis, plus elevation, a MANOVA confirmed that there was a difference in vegetation characteristics in different-aged burns (*F* = 8.95, *P* = 0.0001). I used the first canonical variable (which described 80% of the variation in the data) to investigate which variables were responsible for the greatest amount of variation in the data (Table 2). Sagebrush height and % cover, % total shrub cover, and % grass cover described the greatest amount of variation, with % grass cover having an inverse relationship with sagebrush height and cover and total shrub cover. These canonical coefficients were used to plot the separation of the clusters using a multivariate profile

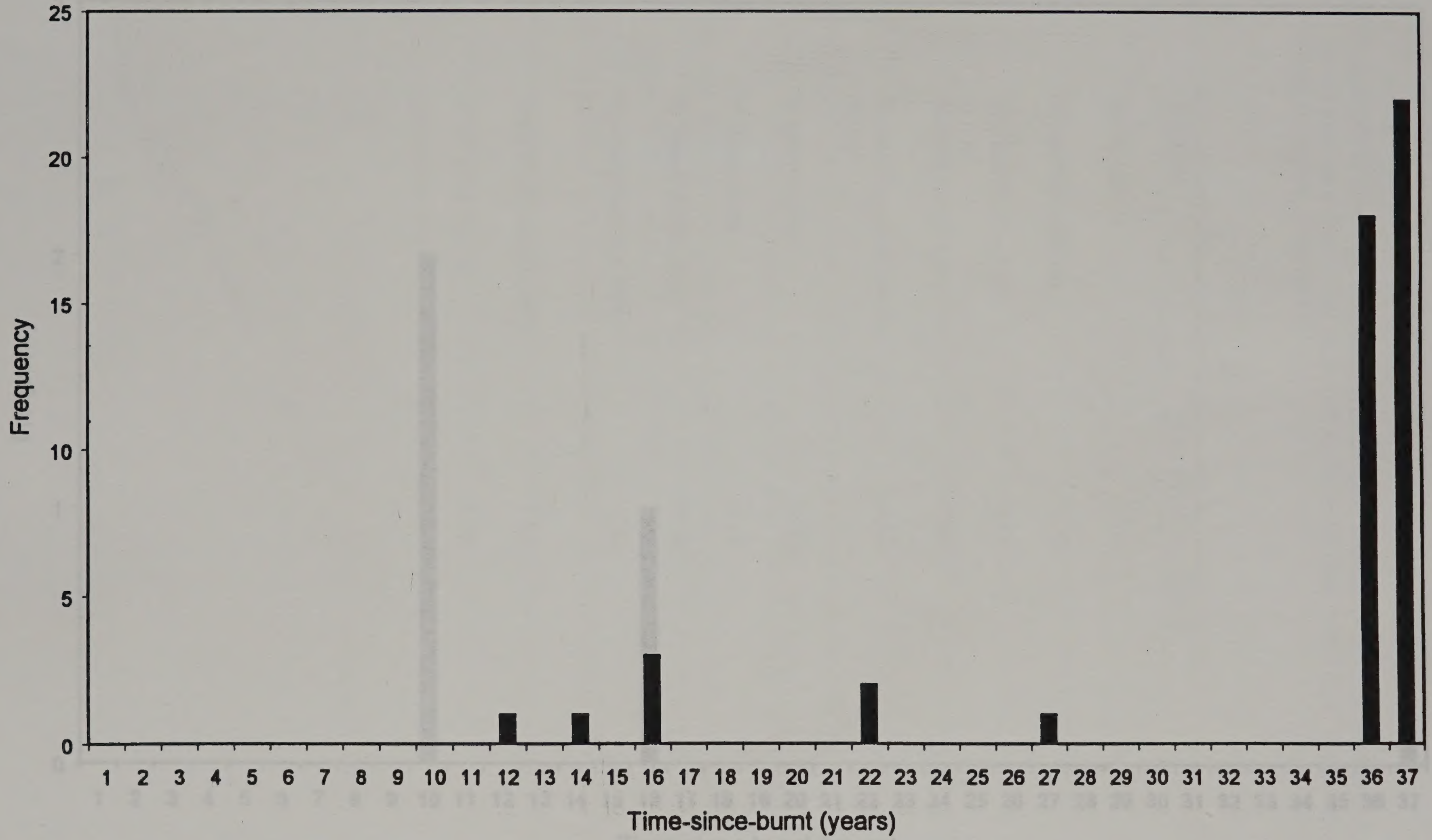

Figure 5. The age range and frequency of occurrence of vegetation in the unburned vegetation group.

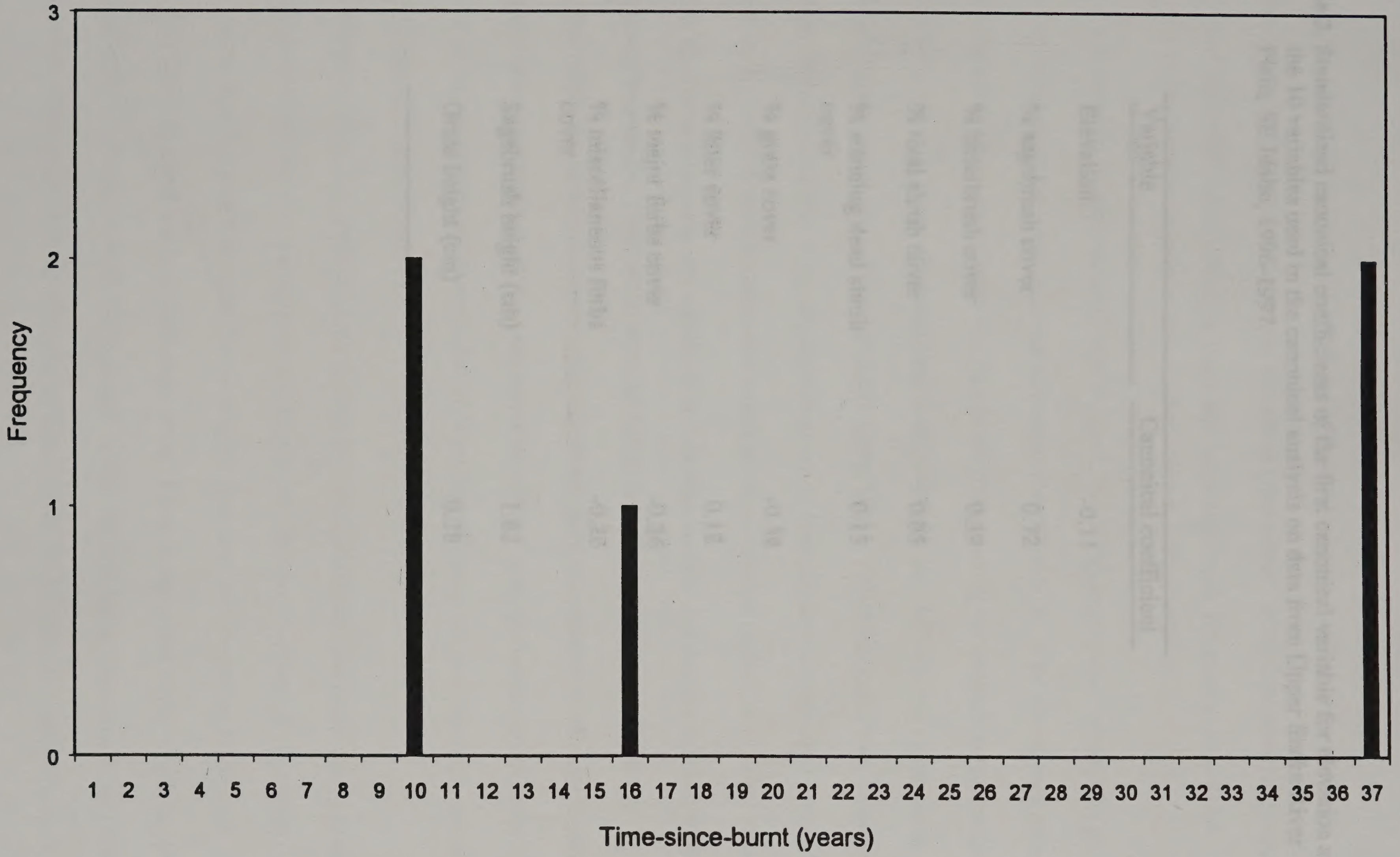

Figure 6. The age range and frequency of occurrence of vegetation in the low elevation group.

Table 2. Standardized canonical coefficients of the first canonical variable for elevation and the 10 variables used in the canonical analysis on data from Upper Snake River Plain, SE Idaho, 1996-1997.

Variable	Canonical coefficient
Elevation	-0.11
% sagebrush cover	0.72
% bitterbrush cover	0.39
% total shrub cover	0.65
% standing dead shrub cover	0.15
% grass cover	-0.58
% litter cover	0.12
% major forbs cover	-0.26
% miscellaneous forbs cover	-0.26
Sagebrush height (cm)	1.82
Grass height (cm)	0.38

(Figure 7). The 1 and 3-5 year old burns typically had less sagebrush cover, smaller sagebrush shrubs, less total shrub cover, and more grass cover. With increasing time-since-burnt vegetation was characterized by more and taller sagebrush and greater total shrub cover.

All variables in the univariate tests differed ($P \leq 0.05$) among the 5 vegetation groups, except for % cover of the major and miscellaneous forbs (Table 3). Post hoc comparisons revealed specific differences (Table 4). Sagebrush canopy cover was significantly less in the 1-year old burn and 3-5 year old burns than in all other groups. At 6-14 years post-burn, sagebrush canopy cover was still significantly lower than in unburned vegetation. The low elevation sites did not differ in sagebrush canopy cover from unburned vegetation and 6-14 year old burns, but had significantly more sagebrush than younger aged burns. Total shrub cover in the 1-year-old group was significantly less than in other age groups and was highest in unburned vegetation. Total shrub cover increased with time-since-burnt (Table 4). Unburned vegetation had significantly taller sagebrush shrubs compared to all other groups except the low elevation sites. The 1-year-old burn and 3-5 year old burns did not differ significantly in sagebrush shrub height, but both had significantly smaller sagebrush shrubs than 6-14 year old burns (Table 4).

Grass cover in 3-5 year old burns and the low elevation sites was significantly greater than the grass cover in the 1-year-old burn, 6-14 year old burns and unburned vegetation. There was no significant difference in the amount of grass cover between the 1-year-old burns, 6-14 year old burns and unburned vegetation. Litter cover in the 1-year-old burn was significantly lower compared to all other groups, which did not differ from each other (Table 4). Although grass height was significantly different in the ANOVA ($P = 0.005$), Tukey's

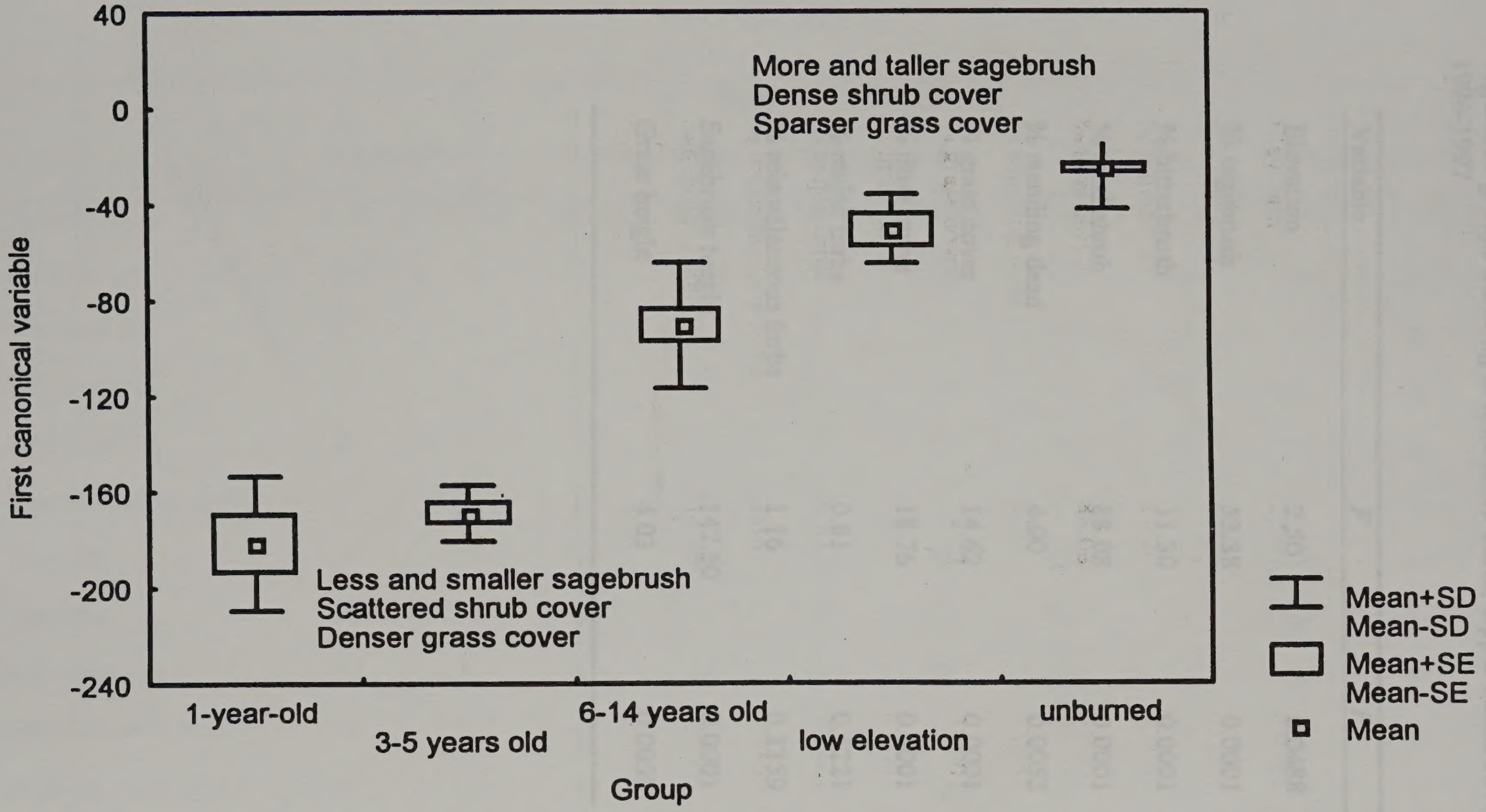

Figure 7. Multivariate profile of the separation of vegetation groups using the coefficients of the first canonical variable from a canonical analysis of vegetation data from the Upper Snake River Plain, SE Idaho.

Table 3. Results of univariate tests for differences in vegetation characteristics among vegetation groups differing in time-since-burnt, Upper Snake River Plain, SE Idaho, 1996-1997.

Variable	*F*	*P*
Elevation	2.50	0.0488
% sagebrush	53.38	0.0001
% bitterbrush	11.30	0.0001
% total shrub	88.08	0.0001
% standing dead	4.00	0.0053
% grass cover	14.62	0.0001
% litter cover	18.76	0.0001
% major forbs	0.81	0.5221
% miscellaneous forbs	1.16	0.3359
Sagebrush height	147.50	0.0001
Grass height	4.03	0.0050

UNIVERSITY OF IDAHO LIBRARY

Table 4. Characteristics of groups identified by cluster analysis of vegetation data from the Upper Snake River Plain, SE Idaho, 1996-1997.

	Group									
	1-year old burn		3-5 year old burns		6-14 year old burns		Low elevation		Unburned vegetation	
Variable	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
Elevation (m)	1698^a	239	1728^a	4310	1759^a	10928	1623^b	7861	1730^a	7643
Sagebrush (%)	0^a	0	0^a	0	8^b	32	12^{bc}	27	18^c	58
Bitterbrush (%)	0^a	0	7^{bc}	22	6^{ab}	31	5^{ab}	43	16^c	83
Total shrub (%)	0^a	0	10^b	17	16^{bc}	45	19^c	27	35^d	63
Standing dead shrub (%)	2^a	3	5^{ab}	8	3^a	5	6^{ab}	28	6^b	12
Grass (%)	25^a	159	48^b	160	33^a	82	65^b	72	34^a	102
Litter (%)	68^a	33	84^b	5	82^b	13	86^b	2	83^b	85
Major forbs (%)	11^a	5	15^a	13	15^a	42	12^a	6	14^a	23
Miscellaneous forbs (%)	10^a	22	17^a	114	15^a	97	13^a	29	12^a	35
Sagebrush height (cm)	9^a	127	11^a	33	49^b	121	63^c	43	71^c	55
Grass height (cm)	17^a	13	26^a	13	19^a	36	26^a	50	24^a	44

Within row means significantly different at $\alpha = 0.05$ have different letters.

multiple comparison test failed to detect where the differences lay (Table 4). This may be because the post-hoc comparison was not sensitive enough to detect where the differences lay, or because there was another comparison other than a pairwise comparison that was significant.

Bitterbrush canopy cover was significantly less in the 1-year-old burn compared with 3-5 year old burns and unburned vegetation (Table 4). Unburned vegetation had significantly more bitterbrush than other groups, except burns from 3–5 years old. However, this is probably a result of high variance in 3–5 year old sites and unburned sites and therefore is not biologically meaningful. The 1-year old burn and 6-14 year old burns had significantly less standing dead shrub cover than unburned vegetation (Table 4).

No significant difference was detected among groups in the abundance of major and miscellaneous forbs (Table 4). The 1-year-old burn had only 10 of 15 genera identified as major forbs present, whereas all of the other burn groups had 12-14 genera present (Table 5). Major food items, common yarrow, lily, hawksbeard, prickly lettuce, dandelion and yellow salsify, did not differ in abundance among different-aged burns (Table 5). Dandelion was the most abundant forb in the 1-year-old burn and in the low elevation sites, rosy pussytoes was the most abundant forb in the 3-5-year-old burns and 6-14-year-old burns, and buckwheat species were the most abundant forb in unburned vegetation.

The number of shrub species in the different groups increased with time-since-burnt and was lowest in the 1-year-old burn group, where only big sagebrush and bitterbrush were recorded. The greatest number of shrub species (9) was found in unburned vegetation, 8 species were recorded in 6-14-year-old burns, 7 species in 3-5-year-old burns and 5 species in the low elevation sites (Table 6).

Table 5. Composition of major forbs in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997.

	Mean % cover of each forb in different-aged burns					
Forb genera	1-year-old burn	3-5-year-old burns	6-14-year-old burns	Low elevation	Unburned (36+ years)	*P*
Achillea*	0.57	1.73	1.08	0.84	1.12	0.11
Agoseris	1.16	0.59	0.71	0.73	0.57	
Allium	0.80	0	0.51	0.67	0.53	
Antennaria	0.52	2.81	3.59	1.33	1.74	
Calochortus*	0	0	0	0.51	0	0.28
Crepis*	0	0	0.53	0.51	0.52	0.23
Erioganum	0.99	1.43	1.6	0.53	2.69	
Lactuca*	0	0.54	0.69	0.57	0.57	0.41
Lupinus	0	0.55	0.51	0.72	0.59	
Lithophragma	1.14	1.41	1.24	0	1.48	
Opuntia	0.51	0.70	0.72	0.74	0.63	
Phlox	0.98	1.63	0.92	1.27	0.89	
Taraxacum*	1.47	1.18	0.84	1.63	0.76	0.07
Tragapogon*	0.68	0.57	0.59	0.93	0.58	0.06
Zygadenus	0	0.51	0.51	0.51	0	

* Major food item for sage grouse

UNIVERSITY OF IDAHO LIBRARY

Table 6. Mean % shrub cover by species in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997.

Shrub species	1-year-old burn	3-5-year-old burns	6-14-year-old burns	Low elevation	Unburned (36+ years)
Mountain big sagebrush	Trace	Trace	8	12	18
Three-tip sagebrush	0	0	Trace	Trace	Trace
Tabaccobrush	0	Trace	Trace	0	Trace
Bitterbrush	Trace	7	6	5	16
Horsebrush	0	0	0	1	Trace
Rabbitbrush	0	Trace	Trace	Trace	Trace
Snowberry	0	Trace	Trace	0	Trace
Serviceberry	0	Trace	Trace	0	Trace
Chokecherry	0	Trace	Trace	0	Trace
Standing dead shrubs	1.9	5	3	6	6

Trace values are <1% canopy cover

Effect of time-since-burnt on invertebrate relative abundance.

Invertebrate relative abundance, measured as the dry weight in grams, differed significantly among vegetation age classes (F=3.16, P=0.001), and I therefore was able to reject the null hypothesis that there is no effect of time-since-burnt on invertebrate abundance. In univariate tests ant and beetle relative abundance differed among vegetation age groups and a canonical analysis revealed that beetle relative abundance was driving the separation of groups (Table 7). There were significantly more beetles in the 1-year-old burn than in all other age groups (Table 8). The 1-year old burn also contained significantly more ants than 3-5 year old burns and unburned vegetation. No significant difference was detected in the dry weight of grasshoppers or miscellaneous invertebrates among different-aged burns (Table 8).

Predicting ant abundance using the density of anthills.

The low elevation group had the greatest number of anthills/100m^2, and the 1-year-old and 3–5 year old burn group had the lowest densities (Table 9), but there was no relationship between the density of anthills and the time-since-burnt ($F = 0.00$, $P = 0.98$, Table 10). No relationship was found between the density of anthills and the number of ants in a burn ($F = 0.43$, $P = 0.51$), nor between the density of anthills and the dry weight of ants ($F = 0.21$, $P = 0.65$, Table 10). I therefore failed to reject the null hypothesis that the density of anthills was uncorrelated with the biomass of ants.

Table 7. Univariate tests for differences in invertebrate relative abundance of different-aged burns, and the first standardized canonical coefficient from a canonical analysis of invertebrate abundance, Upper Snake River Plain, SE Idaho, 1996-1997.

Variable	*F*	*P*	Canonical coefficient
Ants	3.62	0.0093	0.61
Beetles	10.38	0.0001	1.09
Grasshoppers	1.19	0.3235	-0.06
Miscellaneous	0.95	0.4415	-0.21

Table 8. Dry weight (grams) of invertebrates in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997.

	Burn group									
	1-year old burn (n=5)		3-5 year old burns (n=9)		6-14 year old burns (n=16)		Low elevation (n=5)		Unburned vegetation (n=48)	
Variable	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
Ants	0.46^{a}	0.40	0.08^{b}	0.01	0.15^{ab}	0.07	0.25^{ab}	0.09	0.09^{b}	0.02
Beetles	1.7^{a}	1.36	0.39^{b}	0.02	0.42^{b}	0.08	0.73^{b}	0.13	0.54b	0.13
Grasshoppers	0.81^{a}	0.58	0.28^{a}	0.05	1.22^{a}	8.1	0.13^{a}	0.02	0.42^{a}	0.83
Miscellaneous	0.02^{a}	0.00	0.09^{a}	0.00	0.05^{a}	0.04	0.07^{a}	0.00	0.07^{a}	0.01

Within row means significantly different at $\alpha = 0.05$ have different letters.

Table 9. Number of anthills per 100m^2 in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997.

Group	Mean number anthills /100m^2	SE	Minimum anthills/100m^2	Maximum anthills/100m^2
1-year-old burn	5	1	2	7
3–5 year old burns	5	1	1	9
6-14 year old burns	10	3	0	43
Low elevation	17	6	2	36
Unburned (>36 years old)	7	1	0	22

UNIVERSITY OF IDAHO LIBRARY

Table 10. Results of a linear regression modeling the density of anthills against the time-since-burnt, the number of ants and the dry weight of ants caught in pitfall traps, Upper Snake River Plain, SE Idaho, 1996-1997.

Model	Independent variable	Dependent variable	R^2	F	P
1	Age of burn	Density of anthills	0.000	0.000	0.99
2	Anthill density	Number of ants	0.005	0.43	0.51
3	Anthill density	Dry weight of ants	0.003	0.21	0.65

UNIVERSITY OF IDAHO LIBRARY

Sage grouse use of different-aged burns.

Sage grouse used sites within each vegetation group but no significant difference was found in the level of use of different-aged burns ($\chi^2 = 3.71$, $P = 0.45$, Table 11), and I was unable to reject the null hypothesis that the level of use by sage grouse of different-aged burns was similar. I was also unable to reject the null hypothesis that the level of use in different-aged burns was unrelated to the abundance of invertebrates, major forbs and sagebrush height and density ($F = 0.95$, $P = 0.44$).

DISCUSSION

The response of vegetation to fire can vary considerably due to differences in topography, slope, fine fuel load, the moisture content of the vegetation, fire intensity, season of burn and post-burn climatic conditions (Daubenmire 1968, Winward 1985). This inherent variation in vegetation responses to burning can render predicting the long-term effects of fire difficult. Despite the many factors contributing to highly variable responses of vegetation to fire, some clear long-term effects of fire upon sage grouse habitat were detected on the Upper Snake River Plain.

Shrubs are more damaged by burning than forbs and grasses, and except for occasional sprouting by threetip and silver sage (*A. cana*, which was not present within the study area), sagebrushes are nonsprouters and are easily killed by fire (Tisdale and Hironaka 1981, Blaisdell et al. 1982). Although sagebrush was beginning to re-establish in 6-14 year old burns on the Upper Snake River Plain, sagebrush canopy cover 14 years post-burn was still less than half that of unburned vegetation and sagebrush height was only 2/3rd of unburned vegetation. Many factors, such as site characteristics and precipitation, affect the

Table 11. Sage grouse use of different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997.

Group	Number of sign/100m^2	χ^2	*P*
1-year-old burn	12		
3 – 5 year old burns	9		
6 – 14 year old burns	11	3.71	0.45
Low elevation	3		
Unburned (>36 years)	7		

time sagebrush takes to re-establish in an area, but in general mountain big sagebrush usually re-establishes on a site within 5-10 years (Winward 1985), and may return to pre-burn density and cover within 15-20 years post-burn (Bunting et al. 1987). However, severe fires can slow down re-establishment, so that sagebrush takes longer to recover and dominate an area (Bunting et al. 1987). Severe fires may be 1 reason that sagebrush in many of the burns on the Upper Snake River Plain took longer than expected (approximately 15 years, J.W. Connelly, pers. comm.) to return to pre-burn levels. After a severe fire on the US Sheep Experimental Station in SE Idaho, 30 years passed before the sagebrush was once again the dominant species and the initial increases in rabbitbrush and horsebrush decreased to their former low levels (Blaisdell et al. 1982).

Unfortunately, the ability to detect more precisely how long vegetation takes to return to pre-burn conditions on the Upper Snake River Plain was limited by the lack of burns 20-30 years old. The 2 oldest prescribed fires were only 16 years old, and there were only 2 wildfires more than 16 years old (22 and 27 years old). Both 16 year old prescribed burns were clustered with the unburned vegetation, but it was not possible to determine whether this is an accurate estimate of the mean time for the vegetation to return to pre-burn conditions, or the result of light burns and/or favorable post-burn climatic conditions. Information in the burn reports regarding fire intensity is limited and subjective, and provided little help in resolving this question.

Some shrub species, such as rabbitbrush, horsebrush, snowberry and chokecherry sprout profusely after fire (Blaisdell et al. 1982), and were present on the Upper Snake River Plain. Depending on the intensity of the fire, bitterbrush shows a variable response with regard to sprouting after fire, but is moderately adapted to spring and fall fires (Bunting et al.

1987). Unburned vegetation on the Upper Snake River Plain had similar bitterbrush and sagebrush canopy cover, but bitterbrush recovered more quickly after burning and contributed the most to the total shrub canopy cover 3-5 years after burning.

Removing the shrub component through fire may allow grasses and forbs to increase in productivity and abundance. In general, total herbage production of grasses reaches a maximum 2-5 years after burning, after which it declines as the sagebrush and other shrub species increase (Blaisdell et al. 1982, Bunting 1985). In 2 short-term studies, Martin (1990) found significantly more grass cover 2 years post-burn, but Pyle and Crawford (1996) reported a significant reduction in total grass cover 1 year post-burn, and no difference between treatment and controls 2 years post-burn. Grass cover on the Upper Snake River Plain was greatest in 3-5 year old burns which had very sparse shrub cover, and had returned to pre-burn levels by 6-14 years post-burn as the shrub canopy cover increased.

Sagebrush and grass height and % cover are important characteristics of sage grouse nest sites. Sage grouse selectively nest under sagebrush (Patterson 1952, Klebenow 1969, Wallestad and Pyrah 1974, Rothenmaier 1979, Wakkinen 1990, Connelly et al. 1991), and need a minimum of 15% sagebrush cover for successful nesting (Wallestad and Pyrah 1974). On the Upper Snake River Plain only unburned vegetation offered both sagebrush height and cover within the range of nesting conditions reported in the literature (Figures 8 and 9, respectively). Sagebrush shrub height at nests ranges from 36 cm to 70 cm (Patterson 1952, Wallestad and Pyrah 1974, Rothenmaier 1979, Wakkinen 1990), and sagebrush canopy cover ranges from 15-40% (Klebenow 1969, Wallestad and Pyrah 1974, Braun et al. 1977, Rothenmaier 1979). Sagebrush shrub height was within the range used by nesting grouse by

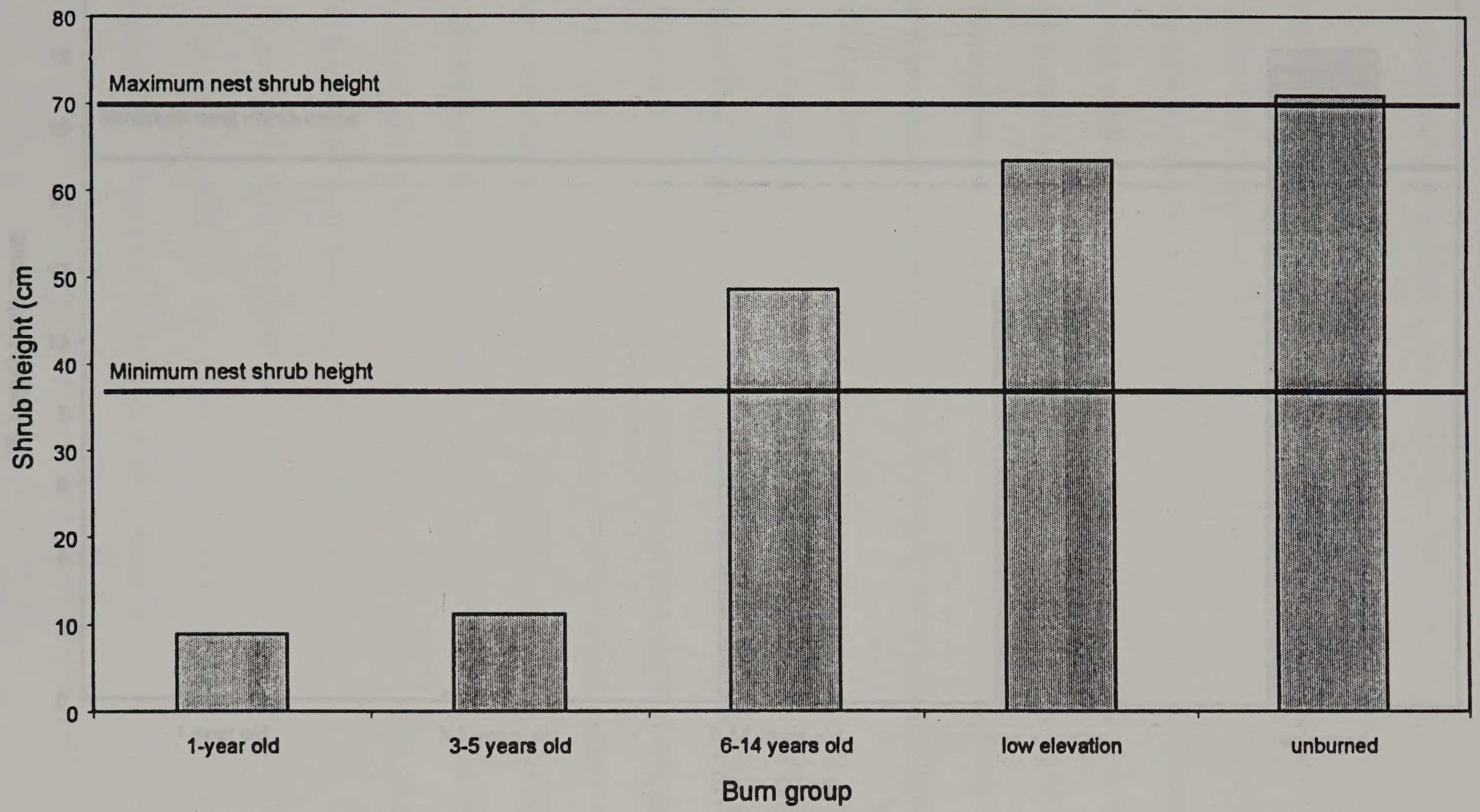

Figure 8. Mean sagebrush shrub height in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature as used by nesting sage grouse.

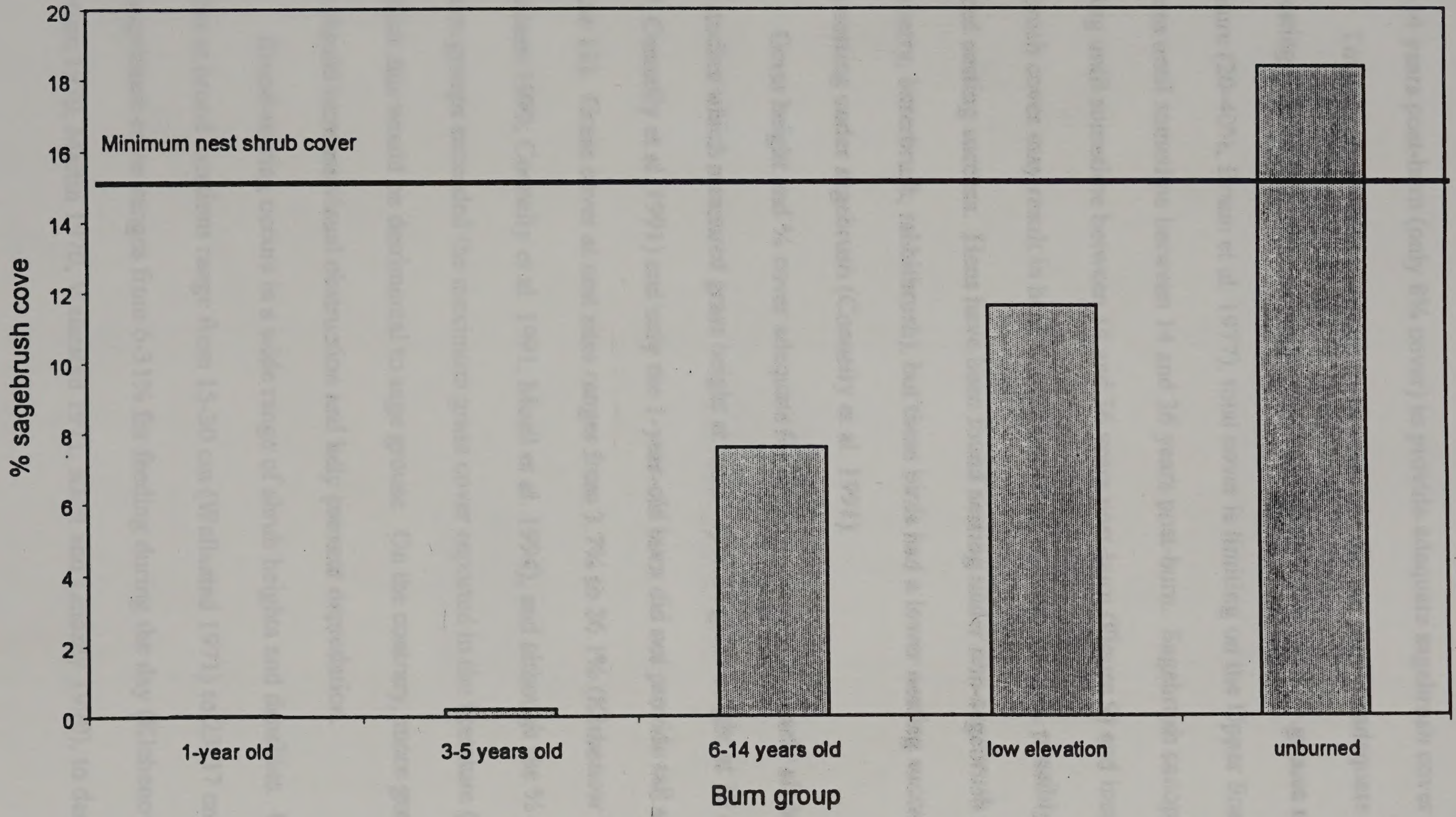

Figure 9. Mean sagebrush % cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the minimum reported in the literature as used by nesting sage grouse.

6-14 years post-burn, but there is insufficient re-colonizing and re-establishment of sagebrush by 6-14 years post-burn (only 8% cover) to provide adequate sagebrush cover for nesting.

Total shrub cover in burns up to 14 years old did not provide adequate nesting canopy for nesting (Figure 10). When compared to total shrub cover used by grouse reported in the literature (20-40%, Braun et al. 1977), total cover is limiting on the Upper Snake River Plain in burns until sometime between 14 and 36 years post-burn. Sagebrush canopy cover is also limiting until sometime between 14 and 36 years post-burn (Figure 9) and insufficient sagebrush cover may result in hens nesting under other shrub species, possibly resulting in reduced nesting success. Hens have been found nesting under non-sagebrush shrubs (e.g. snowberry, bitterbrush, rabbitbrush), but these birds had a lower nesting success compared to birds nesting under sagebrush (Connelly et al. 1991).

Grass height and % cover adequate for nesting occurred in nearly all burn groups. Two studies which measured grass height at nests reported grass height at 19 cm (Wakkinen 1990, Connelly et al. 1991) and only the 1-year-old burn did not provide tall enough grass (Figure 11). Grass cover at nest sites ranges from 3.7% to 26.1% (Klebenow 1969, Wakkinen 1990, Connelly et al. 1991, Musil et al. 1994), and although the % grass cover in all burn groups exceeded the maximum grass cover reported in the literature (Figure 12), I do not think this would be detrimental to sage grouse. On the contrary, more grass cover at nest sites should increase visual obstruction and help prevent depredation.

Brood-rearing occurs in a wide range of shrub heights and densities. Optimum shrub heights at brood locations range from 15-30 cm (Wallestad 1971) to 23-37 cm (Martin 1970), and sagebrush cover ranges from 6-31% for feeding during the day (Klebenow 1969, Peterson 1970, Martin 1970, Wallestad 1971, Klott and Lindzey 1990), to denser cover and

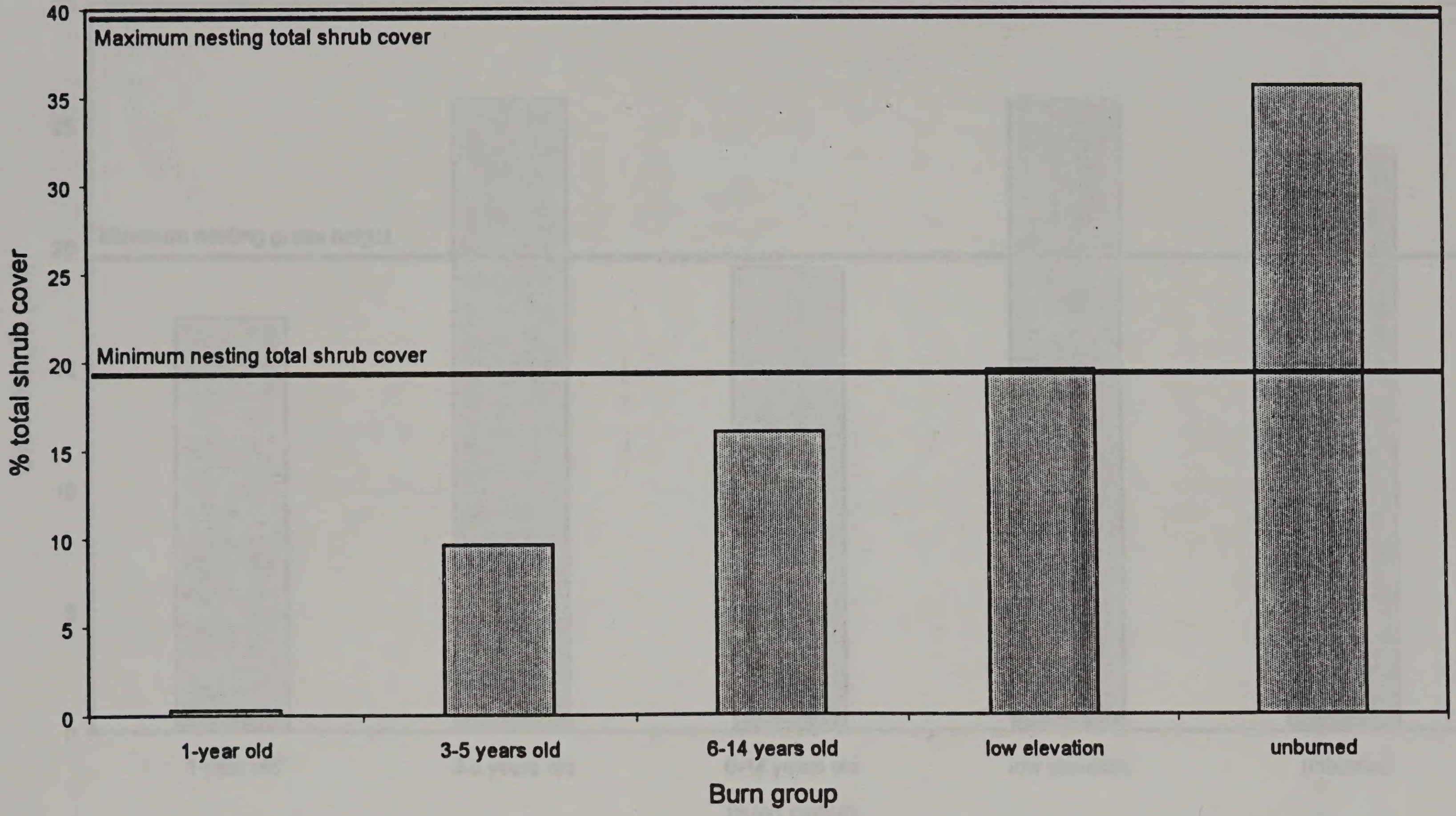

Figure 10. Mean total shrub cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature as used by nesting sage grouse.

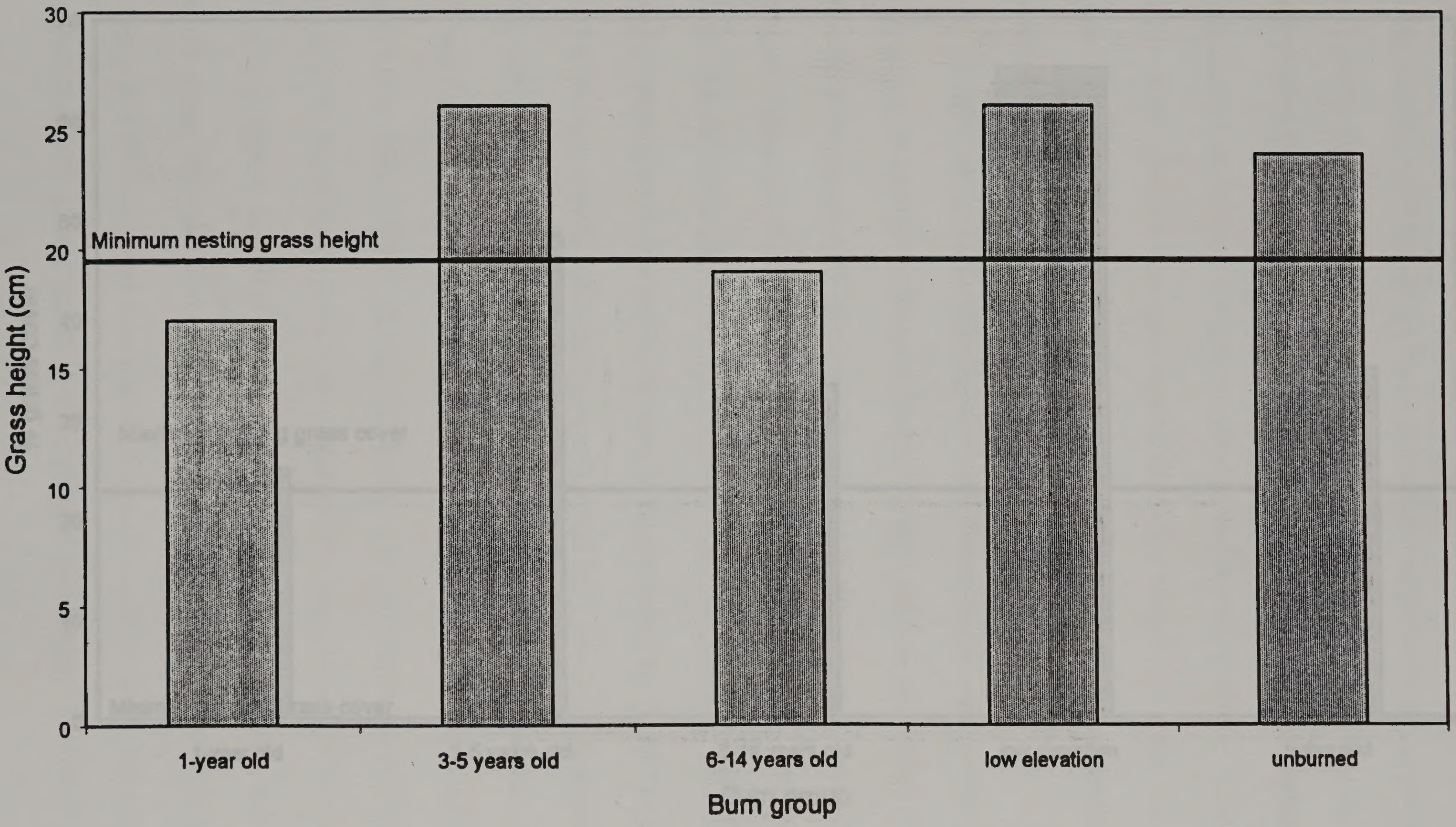

Figure 11. Mean grass height in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the minimum reported in the literature as used by nesting sage grouse.

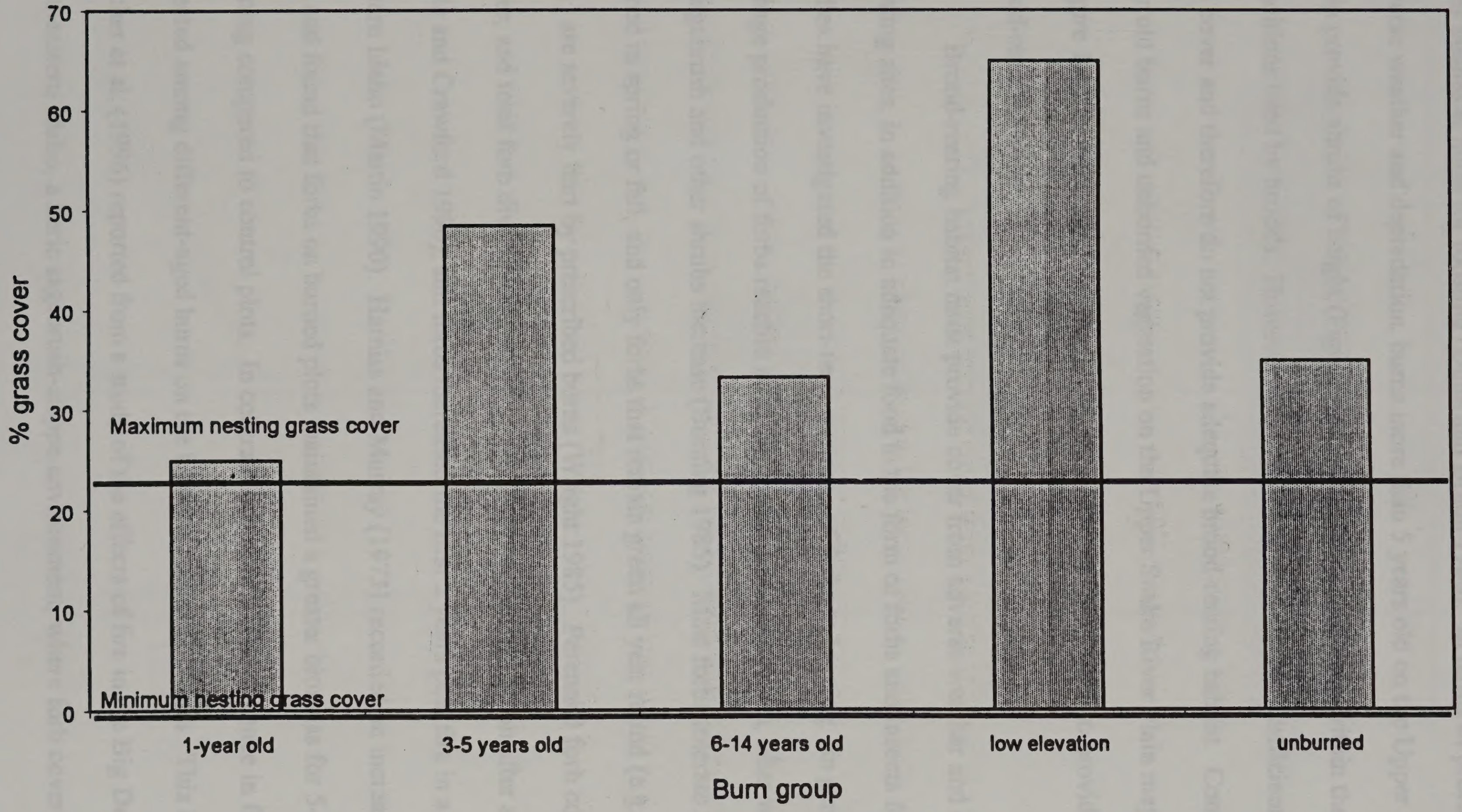

Figure 12. Mean grass cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature as used by nesting sage grouse.

taller bushes at night for roosting (Dunn and Braun 1986). In terms of protection from adverse weather and depredation, burns more than 5 years old on the Upper Snake River Plain provide shrubs of height (Figure 13) and density (Figure 14) within the range of conditions used by broods. However, 1-5 year old burns offered insufficient shrub height and cover and therefore do not provide adequate brood-rearing habitat. Conversely, 6-14 year old burns and unburned vegetation on the Upper Snake River Plain may be too tall (Figure 13) and unburned vegetation may be too dense (Figure 15) to provide adequate brood-rearing habitat.

Brood-rearing habitat must provide cover from adverse weather and depredation, and roosting sites, in addition to adequate food in the form of forbs and insects for chicks. Many studies have investigated the short-term response of forbs to burning. In general, total herbage production of forbs reaches a maximum 2-5 years post-burn, after which it declines as sagebrush and other shrubs increase (Bunting 1985). Most forbs tolerate fire well if burned in spring or fall, and only forbs that remain green all year round (e.g. Eriogonum spp.) are severely hurt by prescribed burns (Wright 1985). Perennial forb cover, total forb cover, and total forb diversity increased in the second growing season after a fire in Oregon (Pyle and Crawford 1996), and forbs increased the first 2 years post fire in a mesic area in eastern Idaho (Martin 1990). Harniss and Murray (1973) recorded an increase in forbs after fire and found that forbs on burned plots maintained a greater biomass for 5-15 years after burning compared to control plots. In contrast, no significant difference in forb cover was detected among different-aged burns on the Upper Snake River Plain. This is similar to what Fischer et al. (1996) reported from a study of the effects of fire in the Big Desert in southeastern Idaho, a xeric sagebrush-steppe environment, where forb cover was similar in

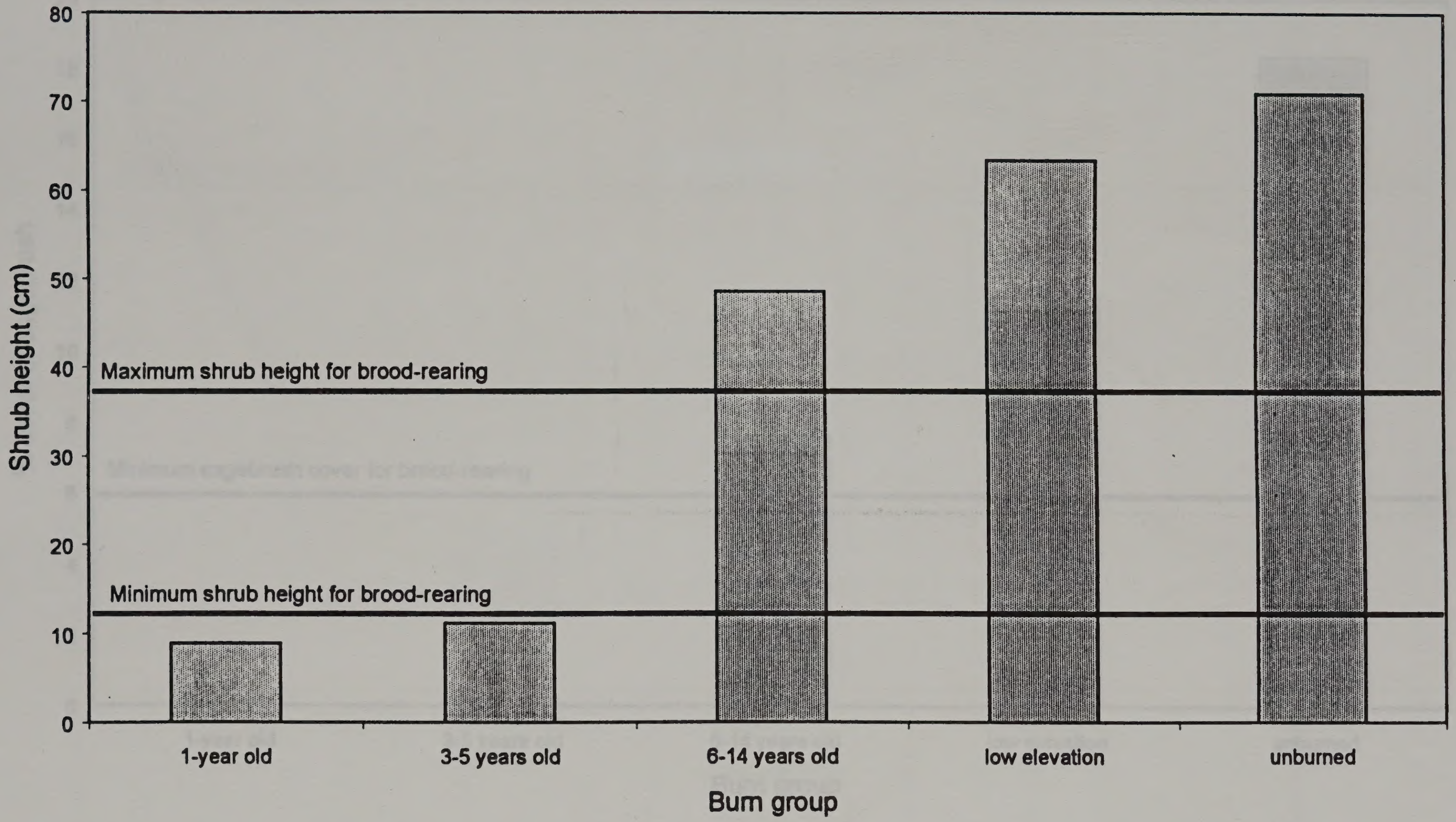

Figure 13. Mean sagebrush shrub height in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature as used during sage grouse brood-rearing.

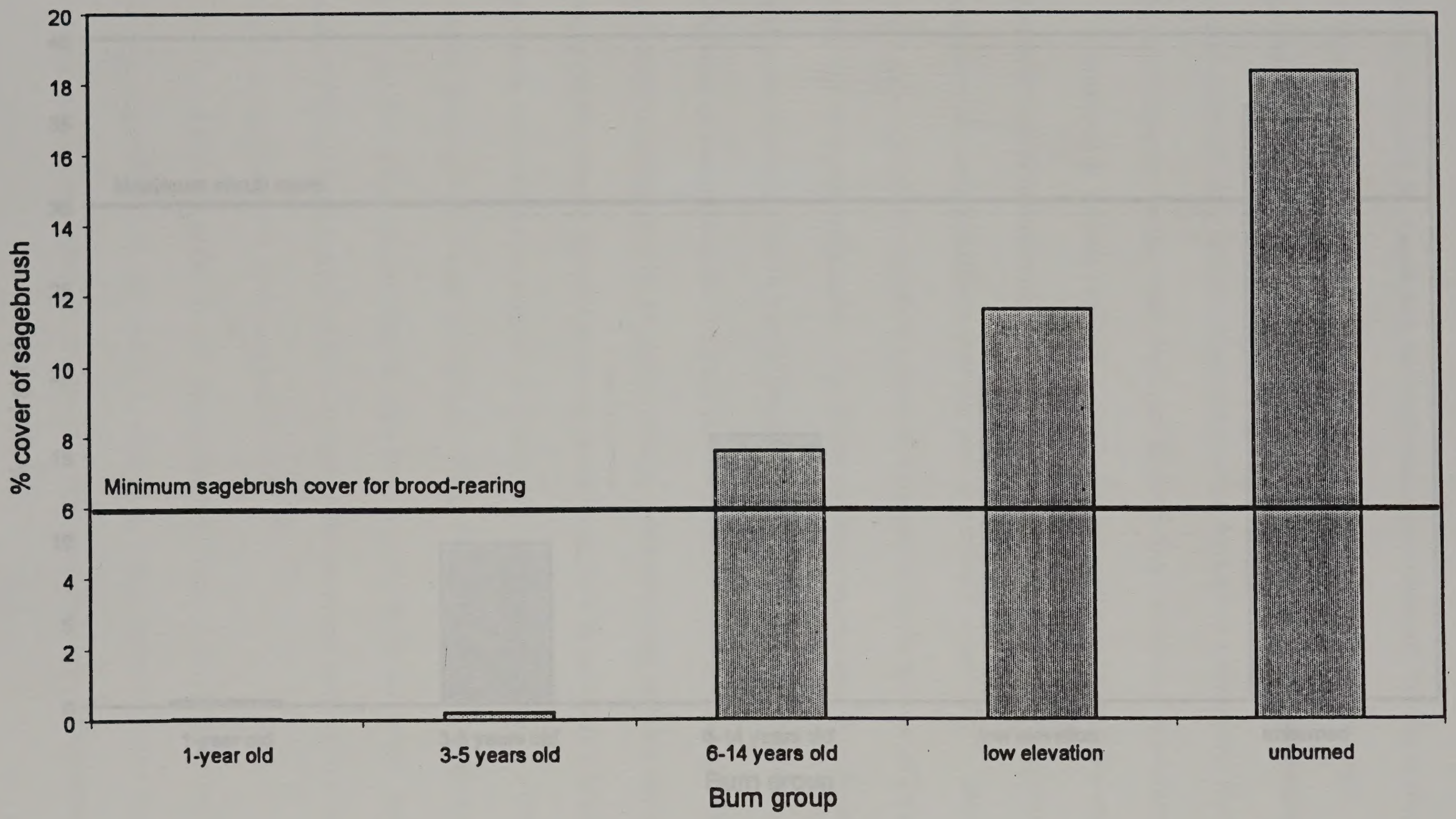

Figure 14. Mean sagebrush % cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the minimum reported in the literature as used during sage grouse brood-rearing.

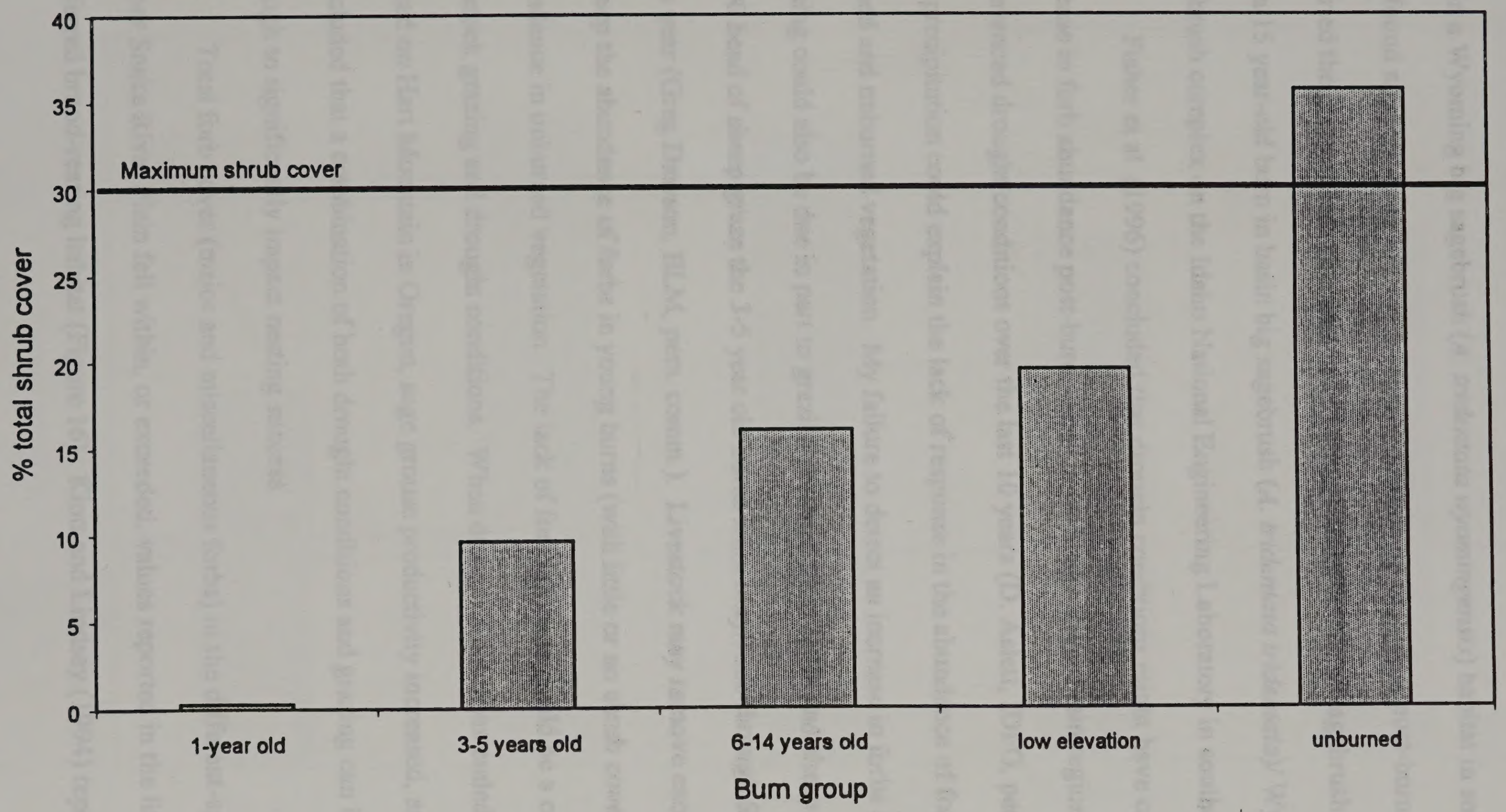

Figure 15. Mean total shrub cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the maximum reported in the literature as used during sage grouse brood-rearing.

burned and unburned habitat up to 3 years post-burn. Clifton (1981) studied the effects of fire in a Wyoming big sagebrush (*A. tridentata wyomingensis*) habitat in south-central Idaho, and found no increase in forbs in burned vegetation up to 2 years post-burn. Simes (1991) reported the greatest forb canopies to be in non-burned stands of sagebrush in a 78-year-old and a 15 year-old burn in basin big sagebrush (*A. tridentata tridentata*)/ Wyoming big sagebrush complex on the Idaho National Engineering Laboratory in southeast Idaho.

Fisher et al. (1996) concluded that drought conditions might have caused the lack of increase in forb abundance post-burn. The Upper Snake River Plain region has also experienced drought conditions over the last 10 years (D. Aslett, IDFG, pers. comm), and low precipitation could explain the lack of response in the abundance of forbs between burned and unburned vegetation. My failure to detect an increase in forbs in response to burning could also be due in part to grazing pressure from cattle and sheep. Approximately 7,900 head of sheep graze the 3-5 year old burns from May/June through September/October each year (Greg Dawson, BLM, pers. comm.). Livestock may remove enough forb biomass to keep the abundance of forbs in young burns (with little or no shrub cover) similar to forb abundance in unburned vegetation. The lack of forb response could be a combination of livestock grazing and drought conditions. When drought conditions ended and cattle grazing ceased on Hart Mountain in Oregon, sage grouse productivity increased, and Coggins (1998) concluded that a combination of both drought conditions and grazing can limit forb cover enough to significantly impact nesting success.

Total forb cover (major and miscellaneous forbs) in the different-aged burns on the Upper Snake River Plain fell within, or exceeded, values reported in the literature as preferred brood-rearing habitat (Figure 16). Klott and Lindsey (1994) reported mean forb

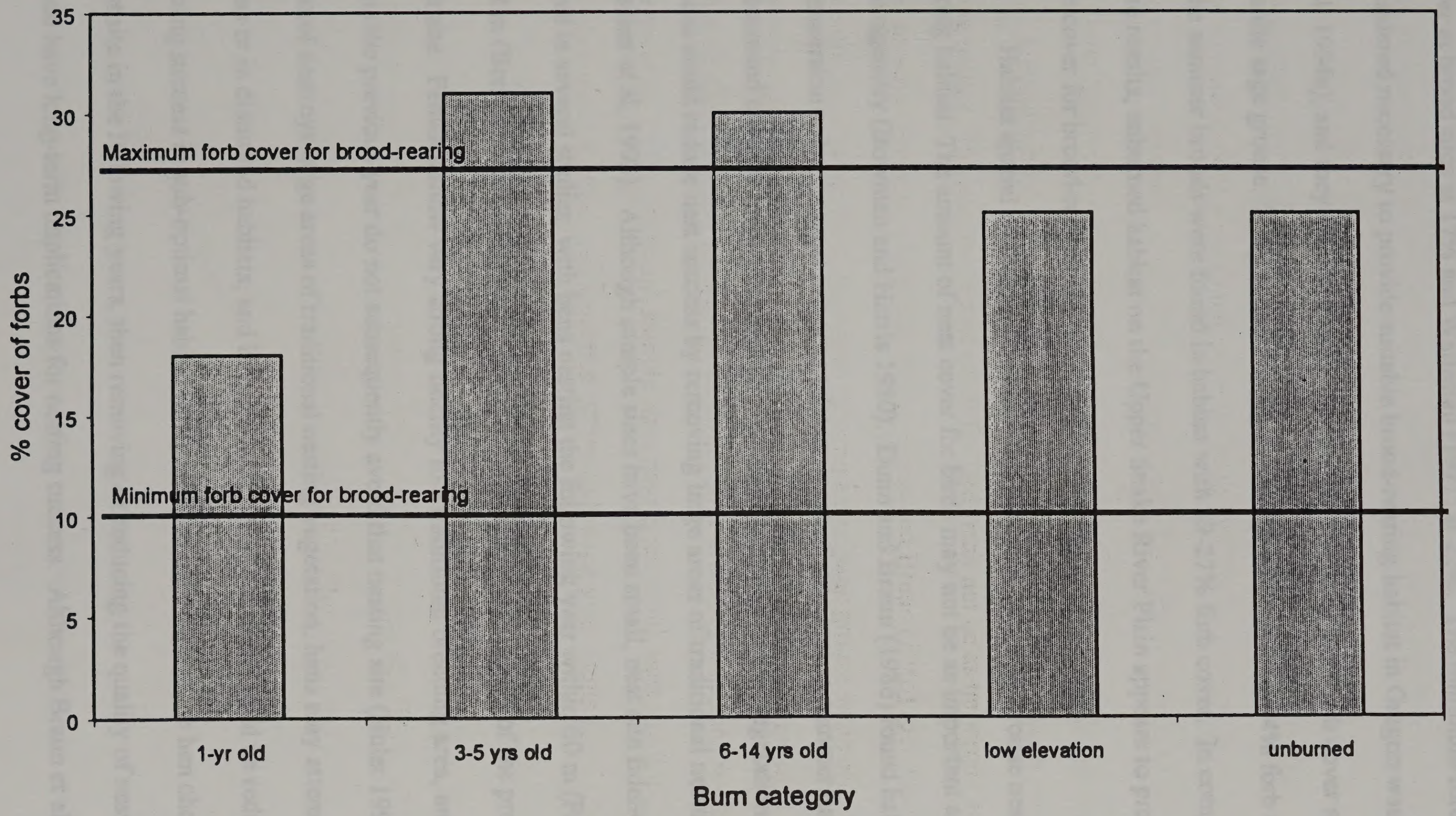

Figure 16. Mean total forb cover in different-aged burn groups on the Upper Snake River Plain, SE Idaho, 1996-1997, in relation to the range reported in the literature used during sage grouse brood-rearing.

cover at brood sites at 17% and Wallestad (1971) at 22%. The minimum forb cover considered necessary to provide suitable brood-rearing habitat in Oregon was 12-14% (Drut et al. 1994a), and they observed a seasonal shift in the amount of forb cover selected by juvenile sage grouse. Early brood-rearing habitat typically had 10-14% forb cover, but later in the summer broods were found in habitat with 19-27% forb cover. In comparison with these results, unburned habitat on the Upper Snake River Plain appears to provide sufficient forb cover for brood-rearing.

Habitat spatial heterogeneity is an important factor in sage grouse nesting and brood-rearing habitat. The amount of nest cover for birds may not be as important as spatial heterogeneity (Bowman and Harris 1980). Dunn and Braun (1986) found habitat interspersion to be the most important determinant of sage grouse summer habitat and did not recommend creating large open areas. Burning extensive areas of vegetation in nesting habitat could reduce nest success by removing large areas of traditional nesting vegetation (Fischer et al. 1993). Although sample sizes have been small, nest site fidelity has been noted in several studies, with hens nesting the following year within 60 m (Patterson 1952), 552 m (Berry and Eng 1985), and 700-1000 m (Fischer et al. 1993) of the previous year's nest site. Females show very strong fidelity to a traditional breeding area, and hens that lose nests the previous year do not subsequently avoid that nesting site (Hulet 1993). If sagebrush control destroys large areas of traditional nesting vegetation, hens may attempt to nest in new areas or in disturbed habitats, and in either case nesting success could be reduced. If reduced nesting success in sub-optimal habitat in 1 year does not result in the hen choosing a new nest site in the following years, then removing or reducing the quality of nesting habitat could have long-term implications for nesting success. Although Braun et al. (1977)

recommended that no sagebrush control take place within 3 km of a lek, Wakkinen et al. (1992) suggested that this buffer zone does not adequately protect nesting sites when many hens nest farther from leks. Larger buffer zones around breeding complexes are probably necessary to protect nesting habitat.

Martin (1990) concluded that broods tolerated extensive open areas while foraging, having found no evidence that broods avoided burned habitat 1 year after a fire even though there was 70% bare ground. However, Klott and Lindsey (1990) noted that broods using large open areas foraged around the edges, and Pyle and Crawford (1996) concluded that burning in montane settings could reduce foraging habitat if an interspersion of treated and untreated sites was not maintained. The size of a burned area will be important as mean daily brood movements are quite small, 400 to 800m (Wallestad 1971), and broods require sagebrush for cover on a daily basis. Recommendations for the size of a burned area range from producing a mosaic of habitats of treated areas not greater than 100 ha (Benson et al. 1991) to 0.4 to 4 ha at elevations used for breeding (Klebenow 1972). Klott and Lindsey (1990) recommended that habitat manipulation be constrained to strips not more than 30 m wide to minimize large open areas that broods did not use. Unfortunately, my study did not measure heterogeneity of habitat and actual burn sizes on the Upper Snake River Plain, and such information was limited in the burn reports. For example, 3 prescribed fires in 1993 were reported as having burned 70 - 80%, 80 - 90%, and 30 - 50% of the area within the burn perimeter, but no information was available on the average size of burned areas, or how isolated/connected were the remaining tracts of unburned habitat.

Wallestad (1971) recommended that large tracts of dense sagebrush with depleted understories were of little value as brood habitat and should be managed by burning to allow

native forbs and grasses to recover and increase in productivity. However, on the Upper Snake River Plain the abundance of major forbs or average grass height in the understory of unburned vegetation was similar to burned vegetation, and the increase in grass cover in burned vegetation was short-lived. Fire may also increase the spread of cheatgrass (*Bromus tectorum*), which is present on Upper Snake River Plain, and was observed to be widespread in many 3-5 year old burns. Burning to "allow native forbs and grasses to recover and increase in productivity" could be difficult to achieve as cheatgrass can become dominant due to disturbance by fire or grazing (Tisdale and Hironaka 1981).

The importance of invertebrates in the diets of 1-week-old chicks has been noted by many studies (Patterson 1952, Klebenow and Gray 1968, Peterson 1970). Although there was significantly more ants and beetles in the 1-year old burns, there was no long-term positive effect on invertebrate abundance in Upper Snake River Plain. From 3 years post-burn onward there was no significant difference in invertebrate abundance compared to unburned vegetation. Fischer et al. (1996) found similar Hymenopteran abundance in burned and unburned habitat 1 year post-burn, but significantly fewer ants 2-3 years post-burn compared with unburned vegetation. The increase in Coleopteran abundance 1 year after fire on the Upper Snake River Plain has not been reported in other studies. Fischer et al. (1996) did not find an effect of fire on Coleopteran abundance, nor did Pyle and Crawford (1996) find an influence of burning on ground-dwelling beetles in Oregon. Rickard (1970) investigating Coleopteran abundance in burned and unburned big sagebrush habitat in southeastern Washington, found that some Coleopteran species were less abundant in burned habitat compared with unburned habitat. Orthopteran abundance did not differ significantly between different-aged burns on the Upper Snake River Plain, which is similar to what

Fischer et al. (1996) reported up to 3 years post-burn. However, Bock and Bock (1991) found reduced Orthopteran abundance 1 year after a fire in an Arizona grassland, but no difference 3 years post-burn.

It is important to question how valuable the initial increase in ant and beetle abundance after a fire is to sage grouse. Very little of the 828 ha, 1-year old burn on the Upper Snake River Plain burned in a mosaic. Instead, shrub cover was completely removed over most of the area. Escape cover was severely limited, rendering chicks more susceptible to depredation when foraging for invertebrates in open areas. Although Martin (1990) concluded that broods tolerated extensive open areas while foraging, and Gates (1983) reported greater use by sage grouse of burned habitat 1 year post-burn, Clifton (1981) found only 19% of sage grouse sightings on or within 15 m of 1- to 2-year-old burn patches. On a 78-year-old burn on the Idaho National Engineering Laboratory in southeast Idaho, Simes (1991) found radio-collared male and female sage grouse used unburned sagebrush more frequently than burned, re-seeded, or naturally re-vegetating sagebrush. Pellet data collected from plots on an adjacent 15-year-old burn indicated that sage grouse used burned areas more in the spring, and unburned areas more in the summer. Benson et al. (1991) monitored the use of burned sites by male sage grouse and found that use was primarily restricted to areas with remnant patches of sagebrush. Fischer et al. (1996) found no large differences in relative abundance of males, females and broods between burned and unburned habitat. Similarly, there was no significant difference in the extent to which sage grouse used different-aged burns on the Upper Snake River Plain. Benson et al. (1991) also found that use of burned sites increased each year post fire, a trend I was unable to detect on the Upper Snake River Plain.

However, due to inherent biases associated with the use plot census, I do not feel my results are an accurate reflection of sage grouse response to different-aged burn groups on the Upper Snake River Plain. Biases include decreasing visibility of sage grouse sign (droppings and feathers) with increasing time-since-burnt and therefore increasing shrub cover, and increasing visibility of droppings as they whiten with age, compared to fresh droppings which are green during the summer months. Using sign as an indication of the amount of use different-aged burn groups receive also does not provide any information on the age or sex class of sage grouse using different-aged burn groups, the type of activity which took place (nesting, brood-rearing, loafing, feeding), or the number of birds using an area.

MANAGEMENT IMPLICATIONS

With regard to sage grouse management, burning to remove sagebrush on the Upper Snake River Plain is rarely justifiable. Unburned vegetation on the Upper Snake River Plain offers suitable nesting and brood-rearing habitat, and Braun et al. (1977) recommended that no control work be considered where live sagebrush cover is less than 20%, as it is in unburned vegetation on the Upper Snake River Plain. If a burn is unavoidable the area targeted should be adequately sampled before the fire is set, to determine whether sage grouse would indeed benefit from burning. If the proposed burn site offers good nesting and brood-rearing habitat, the area should not be burnt. In areas which provide less than adequate nesting habitat burning could enhance brood-rearing habitat in the short term, provided nesting habitat is not limited. Burning to enhance brood-rearing habitat should produce a mosaic of small burned areas interspersed by unburned habitat. The 50% mosaic prescription that is set by the BLM for each burn should be rigorously enforced, and hot,

intense fires that remove all the sagebrush cover should be avoided. Burn patches should be small (less than 100 ha) in order to best safeguard sage grouse nesting and brood-rearing habitat. Small burns will help minimize the long-term negative effects of burning on sagebrush nesting habitat. Small burns interspersed with unburned vegetation will also maximize the short-term benefit to sage grouse chicks of increased ants and beetles 1 year post-burn by providing a mosaic of cover and open areas, thus minimizing the distance to cover from within each open burned area.

Each prescribed fire or wildfire may seem inconsequential when compared to the entire area of sagebrush habitat apparently available to sage grouse on the Upper Snake River Plain. However, the cumulative effect of annual burning upon critical nesting and brood-rearing habitat could be seriously detrimental to the birds if vegetation over a large area remains in sub-optimal conditions for many years. From 1980 to 1996, 11,676 ha have been burned by prescribed fire, which accounts for approximately 29% of the study area, none of which is currently suitable nesting habitat and much of which is not good brood-rearing habitat. Many of these burns are adjoining which creates large contiguous areas of sub-optimal nesting habitat. Managers should plan a burn program that avoids creating large contiguous areas of sub-optimal nesting and brood-rearing habitat. Care should be taken to avoid creating a landscape of young burns located side by side, especially of burns younger than 14 years old. Future research should involve mapping the pattern of burned/unburned vegetation on the Upper Snake River Plain from aerial photographs, ground-truthing and GIS technology, in order to better plan and implement future prescribed burns.

Scheduling when a habitat is burned should not be set by the length of time since an area was last burned. Although it is generally expected that sagebrush will return to its pre-

burn levels on the Upper Snake River Plain by 15 years post-burn, the results of this study demonstrate that this is not the case. Drought conditions and grazing impacts may have slowed the recovery rate of the vegetation, and a monitoring program is needed to follow the recovery of burned vegetation over the entire area. By measuring 3 of the variables identified in the canonical analysis as driving the separation of the burn groups – sagebrush height, % sagebrush canopy cover and % total shrub cover – a fast and efficient monitoring program could be implemented. Permanent, randomly located transects should be established within burned vegetation and vegetation recovery should be monitored annually. The condition of the burned vegetation with respect to sage grouse nesting and brood-rearing habitats could then be evaluated. By monitoring post-burn vegetation land managers could better plan the location and timing of new burns and also better determine when grazing should be allowed to commence on a burn. Grazing should not be allowed on burned habitat until plant development is sufficient to protect the soil from erosion and from invasion by exotics such as cheatgrass. This cannot be determined simply by the time-since-burnt and should be determined by the results of a monitoring program.

Future research should focus on possible long-term effects of burning on sage grouse behavior. It is critical that the response of sage grouse to different-aged burns is documented and monitored by using radio-collared birds, a more effective and efficient method than use plots. Following radio-collared birds would permit determination of what type of habitat (burned or unburned), and the age of the vegetation, that was used for different activities, such as nesting, brood-rearing and roosting. Such a study would also allow the nest and hen success of hens nesting and brood-rearing in different-aged burns to be assessed, along with hen and brood survival. Research is merited on the question of why sage grouse production

has been declining over the long-term. Studies have shown that decreased heterogeneity of habitat increased nest depredation in ground-nesting birds (Bowman and Harris 1980). It is possible that prescribed burning has removed so much shrub cover over large areas that sage grouse nests are now more susceptible to depredation by predators. Burning large areas of sagebrush cover may also render chicks more susceptible to hypothermia in cold, wet springs, by removing or reducing thermal cover.

LITERATURE CITED

Berry, J.D., and R.L. Eng. 1985. Interseasonal movement and fidelity to seasonal use areas by female sage grouse. J. Wildl. Manage. 49:237-240.

Bendall, J.F. 1974. Effects of fire on birds and mammals. Pp. 73-138 in T.T. Kozlowski and C.E. Ahlgren, Eds. Fire and Ecosystems. Academic Press, N.Y.

Benson, L.A., C.E. Braun, and W.C. Leininger. 1991. Sage grouse response to burning in the big sagebrush type. Proc. Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecol. Inst. 5:97-104.

Blaisdell, J.P., R.B. Murray, and E.D. McArthur. 1982. Managing Intermountain Rangelands-Sagebrush-Grass Ranges. USDA For. Serv. Gen. Tech. Rep. INT-134. 36pp.

Bock, C.E. and J.H. Bock. 1991. Response of grasshoppers (Orthoptera: Acrididae) to wildfire in a southeastern Arizona grassland. Am. Midl. Nat. 125:162-197.

Bowman, G.B., and L.D. Harris. 1980. Effect of spatial heterogeneity on ground-nest depredation. J. Wildl. Manage. 44:806-813.

Braun, C.E., T. Britt, and R.O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. Wildl. Soc. Bull. 5:99-106.

Bunting, S.C. 1985. Fire in the sagebrush-grass ecosystems - Successional changes. Pp. 7-11 in Sanders, K., J. Durham, [and others] (eds.) Rangeland Fire Effects – proceedings of a symposium. USDI Bureau of Land Management, Idaho State Office and Univ. of Idaho. 1985. Boise, ID.

BLM LIBRARY
BLDG. 50
DENVER FEDERAL CENTER
P. O. BOX 25047
DENVER, CO 80225-0047

Bunting, S.C., B.M. Kilgore, and C.L. Bushey. 1987. Guidelines for prescribed burning in sagebrush-grass rangelands in the Northern Great Basin. Gen. Tech. Rep. INT-231. USDA For. Serv. Intermountain Res. Sta., Ogden UT. 33pp.

Canfield, R.H. 1941. Application of the line intercept method in sampling range vegetation. J. For. 39:388-394.

Clifton, N.A. 1981. Response to prescribed fire in a Wyoming big sagebrush/bluebunch wheatgrass habitat type. M.S. Thesis, Univ. of Idaho. 39pp.

Coggins, K.A. 1998. Relationship between habitat changes and productivity of sage grouse at Hart Mountain National Antelope Refuge. M.S. Thesis. Oregon State Univ., Corvallis. 32pp.

Connelly, J.W., W. J. Arthur, and O.D. Markham. 1981. Sage grouse leks on recently disturbed sites. J. Range Manage. 34:153-154.

____________,W.L. Wakkinen, A.D. Apa, and K.P. Reese. 1991. Sage grouse use of nest sites in southeastern Idaho. J. Wildl. Manage. 55:521-524.

____________, R.A. Fischer, A.D. Apa, K.P. Reese, and W. L. Wakkinen. 1993. Renesting by sage grouse in southeastern Idaho. Condor 95:1041-1043.

____________, and C.E. Braun. 1997. Long-term changes in sage grouse *Centrocercus urophasianus* populations in western North America. Wildlife Biology. 3:229-234.

Crowley, C.M., and J.W. Connelly. 1996. Sage grouse population and habitat trends in Southeastern Idaho and Southwestern Montana. Unpub. Rep., Idaho Department of Fish and Game, Pocatello, ID. 205pp.

Dalke, P.D., D.B. Pyrah, D.C. Stanton, J.E. Crawford, and E.F. Schlatterer. 1963. Ecology, productivity and management of sage grouse in Idaho. J. Wildl. Manage. 27:811-841.

Daubenmire, R. 1959. A canopy coverage method of vegetational analysis. Northwest Sci. 33:43-64.

____________. 1968. Ecology of fire in grasslands. Pp. 209-266 in Advanced Ecological Research. Vol 5. Ed. J.R. Crogg. Acacademic Press, New York.

Drut, M.S., J.A. Crawford, and M.A. Gregg. 1994a. Brood habitat use by sage grouse in Oregon. Great Basin Nat. 54:170-176.

__________, W.H. Pyle, and J.A. Crawford. 1994b. Technical note: diets and food selection of sage grouse chicks in Oregon. J. Range Manage. 47:90-93.

Dunn, P.O., and C.E. Braun. 1986. Summer habitat use by adult female and juvenile sage grouse. J. Wildl. Manage. 50:228-235.

Edelmann, F.B., M.J. Ulliman, M.J. Wisdom, K.P. Reese, and J.W. Connelly. 1998. Assessing habitat quality using population fitness parameters. A remote sensing/GIS-based habitat-explicit population model for sage grouse (*Centrocercus urophasianus*). Tech. Rep. 25. ID For. Wildl. and Range Expt. Sta., College of For. Wildl. and Range Sci., Univ. of Idaho, Moscow, ID.

Fischer, R.A. 1994. The effects of prescribed fire on the ecology of migratory sage grouse in southeastern Idaho. Ph.D. Thesis, Univ. of Idaho. 150pp.

___________, A.D. Apa, W.L. Wakkinen, K.P. Reese, and J.W. Connelly. 1993. Nesting-area fidelity of sage grouse in southeastern Idaho. Condor 95:1038-1041.

__________, K.P. Reese, and J.W. Connelly. 1996. Influence of vegetal moisture content and nest fate on timing of female sage grouse migration. Condor 98:868-872.

Gates, R.J. 1983. Sage grouse, lagomorph, and pronghorn use of a sagebrush grassland burn site on the Idaho National Engineering Laboratory. M.S. Thesis, Montana State Univ., Bozeman. 135pp.

Gates, R.J. 1985. Observations of the formation of a sage grouse lek. Wilson Bull. 97:219-221.

Hair, J.R., J.F. Rolph, E. Anderson, R.L. Tatham, and W.C. Black. 1995. Multivariate Data Analysis with readings. 4th ed. Prentice-Hall, Englewood Cliffs, NJ. 745pp.

Harniss, R.O., and R.B. Murray. 1973. Thirty years of vegetal change following burning of sagebrush-grass range. J. Range. Manage. 26:322-325.

Hulet, B.V. 1993. Selected responses of sage grouse to prescribed fire, predation and grazing by domestic sheep in southeastern Idaho. M.S. Thesis. Bringham Young Univ., Utah.

Hupp, J.W., and C.E. Braun. 1989. Topographic distribution of sage grouse foraging in winter. J. Wildl. Manage. 53:823-829.

Johnson, G.D., and M.S. Boyce. 1990. Feeding trials with insects in the diet of sage grouse chicks. J. Wildl. Manage. 54:89-91.

Klebenow, D.A. 1969. Sage grouse nesting and brood habitat in Idaho. J. Wildl. Manage. 33:649-662.

____________ 1972. The habitat requirements of sage grouse and the role of fire in management. Proc. Tall Timbers Fire Ecol. Conf. 12:305-315.

_____________, and G.M. Gray. 1968. Food habits of juvenile sage grouse. J. Range Manage. 21:80-83.

Klott, J.H., and F.G. Lindzey. 1990. Brood habitats of sympatric sage grouse and Columbian sharp-tailed grouse in Wyoming. J. Wildl. Manage. 54:84-88.

Martin, N.S. 1970. Sagebrush control related to habitat and sage grouse occurrence. J. Wildl. Manage. 34:313-320.

Martin, R.C. 1990. Sage grouse response to wildfire in spring and summer habitats. M.S. Thesis. Univ. of Idaho, Moscow. 36pp.

Musil, D.D., K. P. Reese, and J.W. Connelly. 1994. Nesting and summer habitat use by translocated sage grouse (*Centrocercus urophasianus*) in central Idaho. Great Basin Naturalist 54:228-233.

Patterson, R.L. 1952. The sage grouse in Wyoming. Sage Books, Denver, Colorado. 341pp.

Peterson, J.G. 1970. The food habits and summer distribution of juvenile sage grouse in central Montana. J. Wildl. Manage. 34:147-155.

Pyle, W.H., and J.A. Crawford. 1996. Availability of foods of sage grouse chicks following a prescribed fire in sagebrush-bitterbrush. J. Range Manage. 49:320-324.

Rickard, W.H. 1970. Ground-dwelling beetles in burned and unburned vegetation. J. Range Manage. 23:293-294.

Robertson, M.D. 1991. Winter ecology of migratory sage grouse and associated effects of prescribed fire in southeastern Idaho. M.S. Thesis. Univ. of Idaho, Moscow. 88pp.

Rothenmaier, D. 1979. Sage grouse reproductive ecology: breeding season movements, strutting ground attendance and site characteristics and nesting. M.S. Thesis, Univ. Wyoming, Laramie. 97pp.

SAS Institute Inc. 1988. SAS/STAT User's Guide, version 6, 4th Edition, Vol 2, Cary, NC. SAS Institute Inc., 1989. 846pp.

Simes, C.A. 1991. Sage grouse use of burned, non-burned, and seeded vegetation communities on the Idaho National Engineering Laboratory, Idaho. M.S. Thesis, Montana State Univ., Bozeman. 72pp.

SPSS Inc. 1992. SPSS/PC+. Advanced Statistics, version 5.0, Ed. Marija J. Norusis/SPSS Inc. 1992. 481pp.

Tisdale, E.W., and M. Hironaka. 1981. The sagebrush-grass region: A review of the ecological literature. Bull. 33. Moscow, Idaho. Forest, Wildlife and Range Experiment Station. 31pp.

Wakkinen, W.L. 1990. Nest site characteristics and spring-summer movements of migratory sage grouse in southeastern Idaho. M.S. Thesis, Univ. of Idaho. 58pp.

____________, K.P. Reese, and J.W. Connelly. 1992. Sage grouse nest locations in relation to leks. J. Wildl. Manage. 56:381-383.

Wallestad, R.D. 1971. Summer movements and habitat use by sage grouse broods in central Montana. J. Wildl. Manage. 35:129-136.

____________. 1975. Male sage grouse response to sagebrush treatment. J. Wildl. Manage. 39:482-484.

____________,and D. Pyrah. 1974. Movement and nesting of sage grouse hens in central Montana. J. Wildl. Manage. 38:630-633.

Winward, A.H. 1985. Fire in the sagebrush-grass ecosystem--The ecological setting. Pp 2-6. in Sanders, K., J. Durham, [and others] (eds.) Rangeland Fire Effects – proceedings of a symposium. USDI Bureau of Land Management, Idaho State Office and Univ. of Idaho. 1985. Boise, ID.

Wright, H.A. 1985. Effects of fire on grasses and forbs in the sagebrush-grass communities. Pp. 12-22 in Sanders, K., J. Durham, [and others] (eds.) Rangeland Fire Effects – proceedings of a symposium. USDI Bureau of Land Management, Idaho State Office and Univ. of Idaho. 1985. Boise, ID.

Zar, J.H. 1984. Biostatisitcal Analysis. 2nd ed. Prentice-Hall, Englewood Cliffs, NJ. 718pp.

Appendix 1. Vegetation characteristics and location of transects within different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997.

Burn group	Transect	Prescribed (P), Wildfire (W) or Unburned (U)	Time-since-burnt (years)	Elevation (m)	UTM location	
					Easting	Northing
1-year-old burn	1	P	1	1683	445833	4889257
	2	P	1	1686	446358	4889724
	3	P	1	1692	446366	4890351
	4	P	1	1707	445471	4891209
	5	P	14	1720	441092	4891295
3-5 year old burns	6	P	5	1655	445124	4886915
	7	P	4	1695	432866	4886301
	8	P	4	1692	432612	4885683
	9	P	4	1692	443002	4889197
	10	P	4	1835	441044	4896933
	11	P	4	1829	440417	4896222
	12	P	3	1732	445448	4894492
	13	P	3	1750	443917	4893515
	14	W	27	1671	431224	4884055
6-14 year old burns	15	P	6	1686	434679	4886442
	16	P	6	1732	434192	4888883
	17	P	5	1646	446622	4886891
	18	P	4	1692	439792	4886656
	19	W	8	1659	437012	4885601
	20	W	8	1643	437408	4885064
	21	W	8	1930	433660	4903061
	22	W	8	1899	431434	4900041
	23	P	14	1726	438697	4888956
	24	P	14	1689	444108	4887509
	25	P	12	1796	442156	4896015
	26	W	14	1713	447103	4894071
	27	W	14	1692	448330	4894270
	28	U	36	1799	434050	4894971
	29	U	36	1905	429299	4902137
	30	U	36	1936	435012	4902275
Low elevation	31	W	10	1564	436368	4877143
	32	W	10	1549	436225	4876062
	33	P	16	1747	431186	4889577
	34	U	37	1686	430518	4885524
	35	U	37	1567	437015	4878255
Unburned	36	P	16	1787	434798	4894253
	37	P	16	1902	433744	4898348
	38	P	16	1747	430258	4889956
	39	P	14	1704	442319	4887544
	40	P	12	1788	442576	4895678

Appendix 1 continued

	41	W	27	1692	430337	4883858
	42	W	22	1905	431003	4903156
	43	W	22	1905	431058	4902898
	44	U	36	1799	437527	4894757
	45	U	37	1756	432755	4891124
	46	U	37	1735	430751	4889005
	47	U	36	1707	441559	4891023
	48	U	36	1735	440448	4891814
	49	U	37	1662	442679	4885122
	50	U	37	1671	443885	4886323
	51	U	36	1796	441126	4895309
	52	U	37	1674	435540	4886012
	53	U	37	1695	435741	4887053
	54	U	37	1640	446228	4887061
	55	U	37	1674	444734	4888334
	56	U	37	1692	431610	4885827
	57	U	37	1713	432901	4887001
	58	U	37	1703	440657	4886750
	59	U	37	1707	441285	4887439
	60	U	37	1878	440573	4899133
	61	U	37	1841	440823	4896772
	62	U	37	1776	442748	4894637
	63	U	37	1735	442048	4892407
	64	U	36	1683	445833	4889257
	65	U	36	1686	446358	4889724
	66	U	36	1692	446366	4890351
	67	U	36	1707	445471	4891209
	68	U	36	1598	440613	4880010
	69	U	37	1741	437501	4889330
	70	U	36	1628	439658	4879026
	71	U	37	1744	436496	4888906
	72	U	36	1604	442569	4882561
	73	U	37	1713	438019	4887492
	74	U	36	1607	438403	4992739
	75	U	37	1768	437153	4890960
	76	U	37	1732	430484	4887491
	77	U	36	1905	429746	4902562
	78	U	37	1726	446591	4895630
	79	U	37	1707	448605	4892396
	80	U	37	1552	436675	4876033
	81	U	36	1643	438334	4884528
	82	U	36	1659	438090	4885441
	83	U	36	1936	432555	4901209
Outlier	84	U	36	1784	443084	4895712

Appendix 2. Shrub composition (% canopy cover) and sagebrush height in different-aged burn groups, Upper Snake River Plain, 1996-1997.

Transect	Mountain big sagebrush	Three-tip sagebrush	Tabaccobrush	Bitterbrush	Horsebrush	Rabbitbrush	Snowberry	Serviceberry	Chokecherry
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.22	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.00
6	0.28	0.00	0.00	5.81	0.00	0.19	0.23	0.17	0.00
7	0.00	0.00	0.00	4.28	0.00	0.00	0.00	0.00	0.00
8	0.05	0.00	0.00	8.58	0.00	0.00	0.00	0.00	0.00
9	0.29	0.00	0.00	4.97	0.00	0.00	0.00	0.00	0.00
10	1.15	0.00	0.00	7.83	0.00	0.00	1.21	0.00	0.00
11	0.03	0.00	4.79	4.99	0.00	0.29	3.25	0.81	0.57
12	0.10	0.00	0.00	14.48	0.00	0.00	0.00	0.00	0.00
13	0.04	0.00	0.00	14.56	0.00	0.00	0.12	0.00	0.00
14	0.00	0.00	0.00	0.61	0.00	6.47	0.00	0.00	0.29
15	0.84	0.00	0.00	5.77	0.00	0.00	0.00	0.00	0.00
16	1.16	0.00	0.04	5.44	0.00	0.25	0.43	0.00	0.00
17	3.76	0.00	0.00	14.14	0.00	0.80	0.00	0.00	0.00
18	0.14	0.00	0.00	5.39	0.00	0.17	0.00	0.00	0.00
19	4.43	8.34	0.00	4.72	0.00	2.19	0.00	0.00	0.00
20	11.97	2.93	0.00	5.65	0.00	0.00	0.00	0.00	0.00
21	6.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	14.21	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.00
23	9.58	0.00	0.00	2.57	0.00	0.00	0.01	0.00	0.00
24	6.76	0.00	11.13	2.13	0.00	0.00	1.34	0.00	0.00
25	9.76	0.00	0.00	6.77	0.00	0.00	0.00	0.00	0.00
26	5.07	0.00	0.00	17.96	0.00	1.42	0.41	1.29	0.00
27	3.39	0.00	2.06	14.79	0.00	5.26	0.00	0.00	0.29
28	7.77	0.00	0.00	9.21	0.00	0.38	0.76	0.00	0.00

Appendix 2 continued.

Total shrub	Standing dead shrub	Sagebrush height (cm)
0.00	2.08	5
0.00	1.76	5
0.00	0.54	4
0.00	4.80	2
1.43	0.50	29
6.66	4.60	20
4.28	5.79	8
8.62	6.63	8
5.25	6.77	13
10.18	9.52	17
14.72	3.90	13
14.58	8.60	10
14.72	1.86	12
7.37	0.86	0
6.61	2.44	41
7.31	4.25	30
18.70	5.43	42
5.69	8.68	29
19.68	0.53	41
20.55	1.87	56
6.13	1.19	35
14.87	0.99	48
12.16	2.79	58
21.36	3.58	57
16.53	0.30	51
26.15	4.71	49
25.79	5.88	59
18.12	4.33	61

Appendix 2 continued

29	16.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	19.17	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00
31	17.50	0.00	0.00	3.03	0.40	0.28	0.00	0.00	0.00
32	10.37	0.00	0.00	0.00	5.64	2.61	0.00	0.00	0.00
33	5.22	0.00	0.00	7.64	0.50	0.09	0.00	0.00	0.00
34	8.64	2.92	0.00	15.65	0.00	0.00	0.00	0.00	0.00
35	16.16	0.00	0.00	0.38	0.00	0.42	0.00	0.00	0.00
36	18.80	0.00	0.00	13.50	0.00	0.19	1.71	0.00	0.00
37	22.94	0.00	0.00	17.86	0.00	0.00	0.47	0.00	0.00
38	17.08	0.38	0.00	26.25	0.00	0.00	0.00	0.00	0.00
39	14.75	0.00	0.00	23.33	0.00	0.14	0.00	0.00	0.00
40	10.26	0.00	0.00	25.46	0.00	0.00	0.00	0.00	0.00
41	10.35	0.00	0.00	24.48	0.00	0.54	0.00	0.00	0.00
42	37.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	21.67	0.00	0.00	10.27	0.00	0.00	0.00	0.00	0.00
44	14.05	0.00	0.00	14.92	0.00	0.00	0.09	0.00	0.00
45	16.80	0.37	0.00	28.53	0.00	0.00	0.00	0.00	0.00
46	19.85	2.60	0.00	26.05	0.00	0.00	0.00	0.00	0.00
47	19.99	0.00	0.00	25.02	0.00	0.00	0.00	0.00	0.00
48	33.97	0.00	5.98	10.57	0.00	0.00	1.09	0.00	0.00
49	8.24	0.00	0.00	15.42	0.00	0.00	0.50	0.00	0.00
50	16.04	0.00	3.83	14.74	0.00	1.18	2.33	0.00	0.00
51	24.55	0.00	16.32	12.63	0.00	0.00	3.18	0.00	4.98
52	15.83	0.51	0.00	8.39	0.00	0.05	0.00	0.00	0.00
53	22.02	0.00	0.00	5.83	0.00	0.00	0.00	0.00	0.00
54	17.37	0.00	0.00	16.66	0.00	1.64	2.00	0.00	0.00
55	19.19	1.70	3.14	7.61	0.00	0.09	0.57	0.03	0.00
56	9.37	0.70	0.00	21.82	0.00	0.00	0.00	0.00	0.00
57	14.15	0.00	0.00	17.55	0.00	0.00	0.00	0.00	0.00
58	5.83	0.00	0.00	28.22	0.00	0.00	0.00	0.00	0.00
59	15.46	0.00	0.11	27.15	0.00	0.16	0.26	0.00	0.00
60	22.13	0.00	0.00	12.78	0.00	0.00	0.05	0.00	0.00

Appendix 2 contined

16.92	3.65	61
19.36	2.04	59
21.21	0.84	60
18.62	3.63	62
13.45	2.05	55
27.21	12.74	72
16.96	10.43	67
34.20	3.41	59
41.27	0.83	70
43.71	8.62	74
38.22	9.53	74
35.72	2.33	54
35.37	4.85	73
37.57	3.02	61
31.94	2.60	60
29.06	1.26	60
45.70	11.60	79
48.50	9.02	73
45.01	2.29	67
51.61	7.83	76
24.16	5.94	74
38.12	6.79	63
61.66	3.02	88
24.77	8.12	71
27.85	10.77	62
37.66	5.37	70
32.32	8.80	82
31.88	13.05	75
31.70	5.81	71
34.04	7.30	58
43.13	6.74	70
34.95	4.62	78

Appendix 2 continued

61	20.90	0.00	0.32	11.99	0.00	0.00	0.14	0.00	0.00
62	22.64	0.00	0.04	16.14	0.00	0.06	0.00	0.00	0.00
63	16.49	0.06	0.00	8.77	0.00	0.00	0.00	0.00	0.00
64	14.45	0.00	0.00	23.09	0.77	0.00	0.00	0.00	0.10
65	21.11	0.00	0.00	23.85	0.00	0.66	0.12	0.22	0.00
66	12.64	0.00	0.00	30.55	0.00	1.73	0.23	0.00	0.00
67	15.49	0.00	0.00	18.43	0.00	0.00	0.00	0.00	0.00
68	11.55	0.00	0.00	12.81	0.00	0.06	0.15	0.00	0.27
69	26.11	0.00	0.00	1.88	0.00	0.00	0.00	0.00	0.00
70	6.94	0.00	0.00	5.34	3.98	1.85	0.00	0.00	0.07
71	22.28	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
72	10.79	0.00	0.00	15.96	0.00	0.00	0.00	0.29	0.56
73	21.63	0.00	0.00	4.59	0.00	0.00	0.00	0.00	0.00
74	21.74	0.17	0.00	13.18	0.14	0.21	0.00	0.00	0.00
75	21.56	0.00	0.00	13.97	0.00	0.00	0.00	0.00	0.00
76	6.04	8.70	0.00	16.38	0.00	0.00	0.00	0.00	0.00
77	37.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	15.87	0.00	0.00	36.96	0.00	1.17	0.00	0.00	0.00
79	16.04	0.00	0.00	20.76	0.00	0.14	0.10	0.97	0.00
80	16.16	0.00	0.00	5.92	0.00	0.00	0.00	0.00	0.00
81	16.11	7.09	0.00	9.79	0.00	0.00	0.00	0.00	0.00
82	18.46	5.97	0.00	8.33	0.03	0.00	0.00	0.00	0.00
83	40.20	0.00	0.00	1.23	0.00	0.00	0.00	0.00	0.00
84	13.57	0.00	0.00	26.59	0.00	0.03	1.33	0.00	0.00

Appendix 2 continued

33.34	6.18	81
38.87	1.89	74
25.32	2.86	69
38.41	1.44	73
45.96	1.39	82
45.15	1.85	59
33.92	2.49	66
24.84	4.92	63
27.99	13.56	82
18.18	2.67	65
22.34	13.82	75
27.60	5.24	60
26.22	5.01	80
35.44	3.22	64
35.53	10.22	73
31.12	8.32	69
37.96	6.64	75
54.00	7.69	76
38.01	11.11	77
22.08	11.07	82
32.99	4.87	77
32.79	5.57	73
41.43	3.33	70
41.52	3.99	66

Appendix 3. % cover of major and miscellaneous forbs, grass, litter and bare ground and grass height in different-aged burn groups, Upper Snake River Plain, 1996-1997.

Transect	Common yarrow	False dandelion	Wild onion	Rosy pussytoes	Lily	Hawksbeard	Buckwheat	Prickly lettuce	Lupine	Prairie starflower	Cactus	Phlox	Dandelion	Yellow salsify	Death camas
1	0.50	0.50	0.50	0.50	0.50	0.50	0.71	0.50	0.50	0.68	0.50	0.56	1.18	0.50	0.50
2	0.74	0.65	0.86	0.50	0.50	0.50	0.53	0.50	0.50	0.80	0.53	0.83	3.43	0.91	0.50
3	0.50	0.74	0.95	0.50	0.50	0.50	1.19	0.50	0.50	2.21	0.50	1.22	1.67	0.65	0.50
4	0.56	3.43	1.19	0.62	0.50	0.50	1.36	0.50	0.50	1.52	0.50	1.19	0.56	0.50	0.50
5	0.56	0.50	0.50	0.50	0.50	0.50	1.18	0.50	0.50	0.50	0.50	1.10	0.53	0.86	0.50
6	1.93	0.53	0.50	1.03	0.50	0.50	1.88	0.52	0.50	0.65	0.61	0.82	0.52	0.50	0.50
7	1.75	0.62	0.50	0.95	0.50	0.50	0.50	0.55	0.59	0.50	0.50	1.49	2.02	0.52	0.52
8	0.50	0.50	0.50	5.07	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.86	4.21	0.50	0.50
9	1.36	0.52	0.50	5.98	0.50	0.50	4.82	0.55	0.50	1.06	0.80	0.56	0.61	0.58	0.52
10	2.79	0.73	0.50	7.74	0.50	0.50	0.61	0.50	0.73	0.65	0.50	2.65	0.74	0.52	0.50
11	2.52	0.89	0.50	1.64	0.50	0.50	1.59	0.50	0.61	1.35	0.50	3.65	0.64	0.50	0.59
12	3.52	0.53	0.50	1.30	0.50	0.50	0.65	0.52	0.56	2.76	0.50	2.00	0.86	0.50	0.50
13	0.70	0.50	0.50	1.07	0.50	0.50	1.75	0.71	0.50	4.75	0.50	1.16	0.55	0.52	0.50
14	0.53	0.53	0.50	0.50	0.50	0.50	0.59	0.50	0.50	0.50	1.90	0.50	0.50	1.01	0.50
15	0.50	0.61	0.53	0.52	0.50	0.50	0.50	0.58	0.50	0.50	0.73	0.74	0.50	0.94	0.53
16	0.95	0.62	0.53	0.99	0.50	0.55	3.15	0.61	0.53	0.50	0.94	1.16	1.22	0.50	0.50
17	0.50	0.59	0.50	0.82	0.50	0.50	0.50	0.52	0.50	2.57	0.55	0.77	1.34	0.52	0.50
18	2.68	0.50	0.50	0.50	0.50	0.50	0.61	1.26	0.55	0.71	1.16	1.31	0.71	0.53	0.50
19	0.83	0.50	0.50	3.46	0.50	0.50	0.50	0.56	0.53	0.50	1.33	1.01	0.53	0.53	0.50
20	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.10	0.56	0.59	0.74	0.50
21	0.50	0.59	0.56	23.23	0.50	0.50	2.63	0.50	0.50	0.50	0.50	0.80	0.53	0.50	0.56
22	0.68	1.70	0.50	1.60	0.50	0.50	0.50	0.50	0.59	0.50	0.50	1.16	0.50	0.50	0.50
23	0.53	0.50	0.50	0.50	0.50	0.50	0.50	2.11	0.50	0.50	0.53	0.50	1.87	0.65	0.50
24	2.38	0.71	0.56	0.50	0.50	0.74	3.04	0.86	0.50	2.55	0.50	2.24	0.65	0.59	0.50
25	1.45	0.89	0.50	1.24	0.50	0.50	0.50	0.50	0.50	0.53	0.98	1.19	1.64	0.50	0.50
26	0.50	0.68	0.50	0.50	0.50	0.53	1.66	0.50	0.50	4.19	0.65	1.10	0.59	0.74	0.50

Appendix 3 continued.

Total forb	Miscellaneous	% grass cover	% litter cover	% bare ground	Grass height (cm)
8.63	4.90	42.89	71.58	22.90	21
12.28	6.29	28.64	68.19	28.74	20
12.63	10.61	15.88	60.48	39.01	14
13.92	16.90	26.92	74.23	23.03	14
9.23	9.37	10.28	63.12	36.20	14
11.48	6.22	56.66	83.56	9.11	26
12.00	6.31	56.13	87.26	4.45	29
17.14	6.84	53.82	85.53	6.70	24
19.34	19.85	29.20	83.03	10.98	18
20.13	22.87	38.67	81.09	15.19	26
16.46	22.37	37.15	81.18	15.90	26
15.70	8.13	70.73	87.50	2.94	27
14.69	23.24	50.44	84.90	7.49	26
9.56	36.68	43.12	83.93	10.07	31
8.66	13.92	46.17	84.17	9.94	24
13.24	13.19	31.72	76.71	19.64	22
11.16	12.73	39.88	83.64	10.73	27
12.51	12.69	35.16	77.78	18.15	22
12.27	6.05	37.26	77.66	15.89	19
8.49	5.89	38.75	74.99	20.80	14
32.90	7.06	22.96	81.35	14.25	8
10.73	13.89	24.41	78.96	16.68	10
10.68	13.18	22.32	83.81	10.63	17
16.81	28.91	36.05	82.05	12.83	27
11.91	18.32	34.06	82.10	12.24	17
13.63	39.03	32.88	81.60	11.69	21

Appendix 3 continued.

27	0.77	1.28	0.50	0.88	0.50	0.65	2.32	0.50	0.50	4.22	0.50	0.62	0.71	0.68	0.50
28	0.59	0.56	0.50	3.89	0.50	0.50	2.19	0.50	0.50	0.50	0.50	0.50	0.53	0.50	0.50
29	3.02	0.53	0.50	15.39	0.50	0.50	2.41	0.50	0.50	0.50	0.50	0.59	0.53	0.50	0.50
30	0.92	0.56	0.50	2.98	0.50	0.50	4.19	0.50	0.50	0.50	0.50	0.50	1.01	0.50	0.50
31	1.06	0.77	0.92	0.50	0.56	0.50	0.50	0.50	0.97	0.50	0.80	0.77	1.24	0.80	0.50
32	0.56	0.53	0.56	0.50	0.50	0.50	0.50	0.50	0.83	0.50	0.56	0.65	0.62	0.53	0.50
33	1.01	0.89	0.62	2.43	0.50	0.56	0.65	0.50	0.50	0.50	0.50	1.91	2.42	0.71	0.50
34	0.53	0.74	0.71	2.52	0.50	0.50	0.50	0.77	0.50	0.50	0.50	2.41	1.45	1.34	0.56
35	1.04	0.71	0.56	0.71	0.50	0.50	0.50	0.56	0.80	0.50	1.33	0.62	2.41	1.25	0.50
36	1.54	0.71	0.50	0.65	0.50	0.50	0.83	0.50	0.50	0.86	0.50	1.97	1.25	0.50	0.50
37	0.50	0.53	0.50	0.86	0.50	0.50	0.50	0.53	0.50	0.53	0.50	1.13	0.50	0.50	0.50
38	1.37	0.56	0.71	0.50	0.50	0.50	1.96	0.50	0.50	0.50	0.50	0.62	0.53	0.80	0.50
39	1.73	0.53	0.56	8.08	0.50	0.50	7.97	0.56	0.50	3.94	0.50	0.56	0.80	0.65	0.50
40	0.86	0.50	0.50	1.24	0.50	0.50	1.03	0.50	0.83	0.59	0.50	0.83	1.27	0.50	0.50
41	0.50	0.59	0.68	0.50	0.50	0.50	0.80	0.53	0.50	0.50	0.50	2.17	0.50	0.74	0.50
42	0.59	0.50	0.50	1.61	0.50	0.50	1.37	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
43	0.50	0.50	0.50	3.14	0.50	0.50	2.12	0.50	0.50	0.50	0.50	0.50	0.74	0.50	0.50
44	0.56	0.56	0.50	0.50	0.50	0.50	5.78	0.50	0.50	0.50	0.50	1.25	0.56	0.80	0.50
45	2.83	0.77	0.53	0.77	0.50	0.50	0.53	0.68	0.50	0.53	1.10	2.33	1.55	0.59	0.50
46	1.79	0.59	0.53	0.50	0.50	1.12	0.50	0.65	0.50	0.50	0.59	0.71	2.54	0.68	0.50
47	1.13	0.50	0.50	0.53	0.50	0.50	3.74	0.50	0.50	0.74	0.68	0.89	0.53	0.50	0.50
48	2.51	0.71	0.50	4.62	0.50	0.50	0.74	0.50	0.68	0.62	0.50	0.77	0.86	0.50	0.50
49	1.28	0.53	0.68	0.50	0.50	0.50	9.05	0.56	0.50	0.56	0.50	0.53	0.50	0.80	0.50
50	1.34	0.71	0.56	1.07	0.50	0.53	3.90	0.56	0.50	4.71	0.71	0.77	0.74	0.50	0.50
51	0.89	0.50	0.50	1.77	0.50	0.50	3.95	0.50	0.50	5.68	0.50	0.50	0.56	0.50	0.50
52	0.65	0.55	0.55	0.50	0.50	0.50	0.50	0.55	0.50	0.50	1.44	0.52	1.16	0.50	0.52
53	0.50	0.61	0.53	0.52	0.50	0.50	0.74	0.55	0.50	1.25	0.53	0.70	0.50	0.53	0.52
54	1.28	0.83	0.58	0.50	0.50	0.50	3.49	0.52	0.50	5.25	1.12	0.79	0.73	0.59	0.50
55	1.19	0.53	0.50	6.70	0.50	0.52	7.68	0.52	0.50	2.68	0.71	0.56	0.71	0.53	0.50
56	1.15	0.53	0.50	2.47	0.50	0.50	0.50	0.59	0.50	0.50	0.55	0.92	1.78	0.62	0.55
57	0.53	0.50	0.61	4.75	0.50	0.50	0.50	0.79	0.50	0.52	0.50	0.98	0.76	0.64	0.50

Appendix 3 continued

15.12	32.28	54.08	86.03	7.81	27
12.76	7.58	27.74	80.58	12.71	18
26.96	6.84	23.67	86.25	5.18	16
14.66	11.66	23.59	86.78	4.47	11
10.88	11.32	62.38	85.75	7.34	24
8.34	13.75	57.28	84.80	10.51	23
14.20	20.30	57.06	86.25	7.02	34
14.02	14.66	72.35	87.25	2.71	31
12.48	5.54	75.25	88.00	3.17	16
11.81	15.33	32.16	87.03	5.35	18
8.58	10.16	33.57	86.75	5.16	18
10.55	16.30	46.06	85.53	5.58	21
27.88	8.35	45.84	88.00	1.76	28
10.64	17.84	29.37	75.75	18.71	19
10.01	24.61	45.75	83.85	8.78	26
9.57	4.01	26.75	83.80	10.42	11
12.00	10.05	17.51	78.33	17.11	15
14.01	7.63	16.82	75.94	19.32	14
14.21	29.04	45.07	88.00	1.82	26
12.19	11.02	42.60	87.50	2.78	21
12.24	13.76	23.32	76.26	21.12	25
15.01	11.56	32.07	85.05	7.52	23
17.49	12.49	30.81	84.55	9.53	25
17.60	15.54	25.01	86.00	6.64	20
17.84	15.40	54.47	88.00	1.55	31
9.41	10.28	40.78	81.52	12.04	23
8.95	11.62	27.83	85.60	7.45	21
17.65	9.92	30.24	84.76	7.31	26
24.31	10.35	34.52	85.01	7.31	21
12.14	6.95	57.49	87.26	3.03	33
13.06	9.35	54.85	85.88	6.30	30

Appendix 3 continued

58	0.52	0.52	0.52	2.20	0.50	0.50	0.91	0.56	0.50	0.71	0.50	0.55	0.58	0.62	0.50
59	0.74	0.58	0.58	9.97	0.50	0.50	6.35	0.50	0.50	0.71	0.50	0.65	0.61	0.55	0.50
60	3.57	0.82	0.55	4.46	0.38	0.38	1.95	0.50	2.17	1.09	0.50	1.21	0.89	0.52	0.50
61	0.92	0.97	0.50	1.25	0.50	0.50	3.06	0.52	0.52	1.18	0.50	1.73	0.55	0.50	0.59
62	0.82	0.52	0.59	0.62	0.50	0.50	1.17	0.50	0.50	0.70	1.52	0.91	0.56	0.59	0.50
63	0.95	0.58	0.55	1.26	0.50	0.50	1.05	0.50	0.78	0.58	0.50	0.77	0.56	0.70	0.50
64	0.62	0.50	0.50	0.65	0.50	0.50	4.71	0.50	0.50	1.22	0.65	0.50	0.56	0.50	0.50
65	0.89	0.50	0.50	0.65	0.50	0.50	8.22	0.50	0.50	3.17	0.68	0.53	0.65	0.53	0.50
66	0.65	0.50	0.50	1.28	0.50	0.50	8.65	0.50	0.50	4.77	0.56	0.65	0.71	0.50	0.50
67	1.13	0.50	0.50	2.81	0.50	0.50	2.21	0.50	0.56	1.22	0.53	0.50	0.56	0.50	0.50
68	0.89	0.50	0.50	2.18	0.50	0.50	1.52	0.50	1.37	0.50	0.68	1.04	0.50	0.92	0.50
69	3.01	0.50	0.53	0.50	0.50	0.50	0.74	0.53	0.50	0.50	0.50	1.91	1.10	0.53	0.50
70	1.01	0.65	0.50	0.68	0.65	0.50	2.96	0.53	0.56	0.50	0.86	1.43	0.86	0.68	0.50
71	1.19	0.59	0.50	1.81	0.50	0.50	1.04	0.53	0.50	0.50	0.50	0.98	0.71	0.50	0.50
72	0.88	0.50	0.50	2.96	0.50	0.50	1.16	0.50	0.68	0.50	0.50	0.59	1.19	0.50	0.50
73	2.03	0.50	0.50	0.50	0.50	0.50	0.50	0.53	0.50	0.77	0.56	0.92	0.80	0.50	0.50
74	0.50	0.50	0.50	0.74	0.50	0.50	0.50	0.50	0.98	0.50	0.50	0.65	0.50	0.80	0.50
75	1.49	0.62	0.65	0.74	0.50	0.50	1.04	0.53	0.50	1.03	0.86	1.19	0.92	0.56	0.50
76	0.50	0.59	0.68	0.50	0.50	0.50	2.29	0.53	0.50	0.50	0.74	1.16	0.50	0.86	0.50
77	1.82	0.50	0.50	0.65	0.50	0.50	12.01	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
78	0.50	0.50	0.50	1.06	0.50	0.50	2.65	0.50	0.50	9.91	0.50	0.65	0.65	0.50	0.50
79	1.64	0.50	0.50	1.16	0.50	0.71	3.44	0.50	0.50	5.29	0.95	0.65	0.53	0.50	0.50
80	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.53	0.50	0.50	0.68	0.50	0.53	0.71	0.50
81	0.50	0.50	0.50	0.83	0.50	0.50	0.50	1.04	0.50	0.50	0.53	0.68	0.50	0.53	0.50
82	0.65	0.50	0.50	0.50	0.50	0.50	0.50	2.02	0.50	0.53	0.65	0.95	0.50	0.50	0.50
83	0.50	0.50	0.50	0.59	0.50	0.50	1.19	0.50	0.50	0.56	0.50	0.50	0.50	0.50	0.50
84	0.59	0.50	0.50	1.24	0.50	0.50	10.57	0.50	0.50	1.55	1.33	0.50	0.71	0.50	0.50

Appendix 3 continued

10.16	10.15	45.52	84.80	7.22	27
23.71	15.45	24.50	86.14	5.60	23
19.45	12.52	41.83	86.38	6.62	20
13.77	21.56	23.42	80.50	14.89	17
10.48	20.84	19.58	79.57	16.61	21
10.25	14.94	30.81	76.05	18.74	23
12.91	12.36	40.14	70.20	19.84	34
18.82	3.91	36.81	85.18	4.79	30
21.26	8.12	23.77	79.83	12.98	24
13.02	7.61	27.08	76.13	17.04	23
12.60	5.69	31.98	85.53	7.83	45
12.35	22.05	20.03	80.13	15.52	20
12.87	8.52	38.09	82.90	8.86	40
10.85	22.13	31.98	83.75	10.84	15
11.96	4.90	36.01	87.75	4.33	36
10.11	24.54	22.70	84.46	10.03	17
8.67	6.35	29.54	81.48	14.76	23
11.63	16.94	26.61	82.53	12.05	24
10.85	9.53	44.89	84.30	7.05	28
20.48	4.99	27.03	83.35	11.48	17
19.91	12.43	43.45	86.00	6.25	23
17.87	12.27	46.90	84.53	6.29	27
7.95	12.25	44.69	85.30	7.87	25
8.61	5.87	47.80	86.78	5.00	22
9.80	5.77	46.89	86.55	4.77	24
8.34	9.49	27.32	82.78	10.29	14
20.48	13.33	26.89	76.56	19.81	29

Appendix 4. Dry weight and numbers of invertebrates collected in pitfall traps in different-aged burn groups, Upper Snake River Plain, 1996-1997.

Transect	Ant dry weight (g)	# ants	Beetle dry weight (g)	# beetles	Grasshopper dry weight (g)	# Grasshoppers	Jerusalem Cricket dry weight (g)	# Jerusalem Crickets	Miscellaneous dry weight (g)	# miscellaneous
1	1.58	408	1.00	21	1.92	25	0.00	0	0.01	3
2	0.12	202	1.31	32	0.27	6	0.00	0	0.00	4
3	0.30	409	3.14	81	0.19	3	0.00	0	0.01	3
4	0.16	160	2.70	75	1.29	24	0.00	0	0.02	6
5	0.14	193	0.38	11	0.39	17	0.04	1	0.07	23
6	0.03	46	0.39	7	0.35	6	0.00	0	0.05	10
7	0.05	112	0.31	6	0.76	10	0.06	0	0.03	10
8	0.13	99	0.42	9	0.07	7	0.00	0	0.23	22
9	0.04	85	0.56	16	0.17	6	0.00	0	0.05	17
10	0.04	65	0.28	12	0.33	7	0.05	1	0.01	8
11	0.35	213	0.46	24	0.09	3	0.19	1	0.11	11
12	0.02	45	0.32	22	0.36	7	0.00	0	0.05	20
13	0.03	70	0.15	8	0.27	5	0.00	0	0.04	7
14	0.04	33	0.59	19	0.16	8	0.24	1	0.25	21
15	0.12	157	0.21	4	0.19	7	0.00	0	0.06	24
16	0.05	107	0.41	10	0.13	5	0.04	0	0.03	12
17	0.05	78	0.32	16	0.30	10	0.15	1	0.20	14
18	0.03	89	1.17	25	0.44	6	0.02	0	0.09	27
19	0.03	55	0.23	6	0.00	1	0.18	1	0.03	9
20	0.07	65	0.39	4	0.00	1	0.00	0	0.01	6
21	0.02	29	0.30	5	0.06	3	0.00	0	0.01	5
22	0.88	492	0.59	11	0.07	4	0.00	0	0.05	11
23	0.79	267	0.22	5	0.03	1	0.00	0	0.04	26
24	0.05	44	0.63	12	6.35	54	0.00	0	0.03	12
25	0.03	84	0.64	23	0.14	4	0.26	1	0.09	16
26	0.03	53	0.83	20	1.71	23	0.24	1	0.09	14

Appendix 4 continued

27	0.08	169	0.41	10	10.11	51	0.00	0	0.04	13
28	0.03	20	0.23	6	0.04	1	0.00	0	0.03	5
29	0.05	168	0.17	3	0.04	1	0.00	0	0.04	8
30	0.12	108	0.07	6	0.01	1	0.00	0	0.02	11
31	0.44	276	0.54	5	0.01	4	0.08	1	0.06	20
32	0.71	442	0.62	12	0.33	17	0.09	1	0.07	28
33	0.04	76	1.11	13	0.06	5	0.20	1	0.01	10
34	0.02	23	0.30	10	0.06	1	0.00	0	0.09	18
35	0.06	86	1.09	23	0.17	7	0.00	0	0.13	26
36	0.08	69	0.26	5	0.00	0	0.00	0	0.08	10
37	0.09	93	0.26	12	0.02	1	0.00	0	0.02	3
38	0.03	41	0.54	13	0.11	5	0.00	0	0.07	17
39	0.03	21	0.40	11	1.61	13	0.00	0	0.06	30
40	0.04	70	0.46	14	0.11	3	0.00	1	0.08	17
41	0.06	38	0.93	16	0.18	5	0.29	1	0.06	19
42	0.04	123	0.18	15	0.00	0	0.00	0	0.02	11
43	0.48	301	0.17	15	0.04	1	0.00	0	0.03	11
44	0.06	40	0.38	10	0.05	3	0.00	0	0.28	12
45	0.04	24	0.63	14	0.02	1	0.00	0	0.09	22
46	0.05	81	0.86	12	0.04	1	0.00	0	0.02	10
47	0.04	80	0.74	12	0.07	4	0.00	0	0.01	5
48	0.16	235	0.47	14	0.01	1	0.00	0	0.07	18
49	0.03	28	0.62	13	2.36	34	0.09	1	0.03	12
50	0.06	40	0.99	8	5.83	39	0.00	0	0.05	2
51	0.07	175	1.58	32	0.10	3	0.00	0	0.23	23
52	0.04	47	0.38	7	0.17	6	0.00	0	0.02	10
53	0.07	66	0.31	8	0.06	2	0.00	0	0.02	10
54	0.04	43	0.37	15	0.18	9	0.08	0	0.10	46
55	0.07	50	1.42	34	0.91	14	0.00	1	0.15	34
56	0.01	35	0.54	9	0.81	5	0.00	0	0.07	15
57	0.07	70	0.29	7	0.08	3	0.00	0	0.06	17

Appendix 4 continued

58	0.03	34	0.85	14	0.54	5	0.03	0	0.07	17
59	0.28	40	0.49	6	0.67	9	0.13	1	0.08	21
60	0.03	82	1.05	16	0.33	6	0.34	2	0.08	12
61	0.17	139	0.38	16	0.43	5	0.13	1	0.08	12
62	0.59	260	0.38	14	0.09	2	0.00	0	0.04	14
63	0.03	36	0.94	16	0.21	6	0.05	0	0.06	21
64	0.05	68	0.41	14	0.35	7	0.00	0	0.05	17
65	0.04	31	0.16	6	0.18	4	0.00	0	0.03	7
66	0.10	124	0.20	8	0.43	6	0.00	0	0.11	29
67	0.02	28	0.33	17	0.23	6	0.00	0	0.08	16
68	0.30	225	0.14	5	0.01	1	0.00	0	0.03	19
69	0.06	119	0.27	11	0.08	4	0.00	0	0.04	16
70	0.08	74	0.28	7	0.07	2	0.07	1	0.04	5
71	0.04	64	0.15	9	0.30	8	0.00	0	0.48	11
72	0.09	79	0.33	8	0.23	2	0.00	0	0.02	10
73	0.03	54	1.49	18	0.43	5	0.00	0	0.08	7
74	0.03	33	0.16	4	0.00	0	0.00	0	0.02	6
75	0.04	118	0.74	8	0.31	9	0.00	0	0.06	12
76	0.01	37	0.53	17	0.09	4	0.04	1	0.08	14
77	0.45	217	0.91	22	0.00	1	0.00	0	0.02	19
78	0.02	67	0.93	21	0.57	6	0.00	0	0.04	12
79	0.02	27	0.60	15	0.46	9	0.00	0	0.18	33
80	0.05	69	0.89	17	0.14	7	0.00	0	0.02	17
81	0.02	26	0.18	2	0.06	3	0.00	0	0.02	7
82	0.11	69	0.32	7	0.41	4	0.00	0	0.02	7
83	0.06	229	0.19	17	1.01	2	0.00	0	0.03	16
84	0.03	51	0.71	12	0.53	6	0.01	1	0.06	12

Appendix 5. Numbers of sign of sage grouse in use plots and density of anthills in different-aged burn groups, Upper Snake River Plain, SE Idaho, 1996-1997.

Transect	Jun-96	Jul-96	Jun-97	Jul-97	Total # sign	# anthills/100m2
1	20	13	.	.	33	3
2	.	.	1	14	15	6
3	.	.	0	1	1	6
4	.	.	0	4	4	7
5	.	.	0	9	9	2
6	0	0	0	0	0	2
7	0	3	1	0	4	6
8	0	5	0	0	5	6
9	4	3	3	0	10	1
10	0	1	3	0	4	4
11	1	2	28	2	33	4
12	2	3	0	3	8	5
13	8	7	0	2	17	9
14	.	.	0	0	0	4
15	1	16	.	.	17	13
16	.	.	17	13	30	3
17	0	2	.	.	2	6
18	0	5	0	0	5	7
19	3	13	20	1	37	19
20	0	1	1	0	2	31
21	6	4	12	4	26	4
22	.	.	0	2	2	0
23	.	.	0	0	0	2
24	0	0	.	.	0	2
25	1	0	.	.	1	7
26	32	10	.	.	42	9
27	4	2	.	.	6	5
28	0	0	.	.	0	6
29	0	1	.	.	1	1
30	0	0	.	.	0	43
31	.	.	4	0	4	36
32	.	.	0	0	0	27
33	.	.	0	0	0	5
34	.	.	8	2	10	2
35	.	.	0	0	0	17
36	3	1	.	.	4	2
37	1	0	.	.	1	2
38	.	.	0	2	2	4
39	.	.	3	0	3	3
40	4	0	.	.	4	9
41	.	.	2	0	2	13

Appendix 5 continued.

42	0	0	.	.	0	4
43	3	1	.	.	4	4
44	3	0	.	.	3	1
45	.	.	0	2	2	4
46	.	.	0	6	6	15
47	5	5	.	.	10	4
48	0	13	.	.	13	1
49	.	.	4	3	7	5
50	.	.	10	0	10	10
51	4	0	.	.	4	3
52	0	4	2	0	6	10
53	12	6	2	0	20	8
54	11	4	0	0	15	5
55	0	0	0	4	4	2
56	0	0	2	0	2	2
57	1	7	0	0	8	10
58	9	3	14	17	43	5
59	2	1	0	2	5	3
60	13	2	5	0	20	4
61	19	7	9	11	46	6
62	8	6	0	2	16	14
63	5	6	4	3	18	11
64	0	1	.	.	1	0
65	4	0	.	.	4	1
66	9	5	.	.	14	2
67	3	4	.	.	7	4
68	7	0	.	.	7	13
69	.	.	0	0	0	2
70	8	0	.	.	8	17
71	.	.	0	0	0	2
72	7	0	.	.	7	14
73	.	.	0	0	0	8
74	0	0	.	.	0	14
75	.	.	2	0	2	4
76	.	.	3	2	5	3
77	1	0	.	.	1	1
78	.	.	0	0	0	12
79	.	.	0	0	0	7
80	.	.	0	0	0	22
81	0	3	.	.	3	12
82	0	0	.	.	0	10
83	11	4	.	.	15	2
84	4	0	.	.	4	7

No count indicates use plots not searched in that year.

BLM LIBRARY
BLDG. 50
DENVER FEDERAL CENTER
P. O. BOX 25047
DENVER, CO 80225-0047